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# MONTHLY NOTICES

OF THE

# ROYAL ASTRONOMICAL SOCIETY.

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## ANNUAL REPORT OF THE COUNCIL.

Vol. LIII. No. 4. February 1893.

Fellows of the Society are informed that post-cards containing the titles of papers to be read at the evening meetings will be sent to those who shall express their wish to receive them. Fellows desiring to receive the post-cards are requested to send their names to the Assistant-Secretary, Mr. W. H. Wesley, Burlington House, London, W.

In order to enable the Secretaries to prepare complete lists in time for the issue of the post-cards, authors are particularly requested to send in their papers not later than the Tuesday preceding the day of meeting.

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Fellows are informed that Vol. L. of the *Memoirs* is now published, and may be had on application at the apartments of the Society; or will be sent post free on receipt of a written request to that effect, addressed to the Assistant-Secretary.

*The price of Vol. L. to the public is* 12*s.* 6*d.*

# MONTHLY NOTICES

OF THE

# ROYAL ASTRONOMICAL SOCIETY.

Vol. LIII. February 10, 1893. No. 4

E. B. KNOBEL, Esq., President, in the Chair.

Harold John Adams, M.A., St. John's, Cedars Road, Beckenham, S.E.;
Samuel Barker, 9 Hanover Terrace, Regent's Park, N.W.;
Pat Doyle, F.R.S.E., M.R.I.A., 19 Lall Bazar Street, Calcutta;
Rev. Edwin G. Gange, 135 King Henry's Road, South Hampstead, N.W.;
John Spencer, F.G.S., Rock House, Crawshaw Booth, near Manchester;
Anthony Standidge Thomson, Lieut. R.N.R., F.R.G.S., F.R.M.S., A.I.E.E., Telegraph Works, Silvertown, Essex,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers, from personal knowledge, being appended:—

Ludwig Becker, Ph.D., Professor of Astronomy and Director of the Observatory in the University of Glasgow (proposed by Dr. R. Copeland);
Bernard Edward Cammell, Folly Court, Wokingham, Berks (proposed by George Calver);
Raymond Hill Godfrey, 79 Cornhill, E.C. (Stock Exchange), and Firview, Claygate, near Esher, Surrey (proposed by Professor C. Pritchard);
Samuel Marcus Russell, Professor of Mathematics and Astronomy, Imperial College, Pekin (proposed by Sir R. S. Ball).

## Report of the Council to the Seventy-third Annual General Meeting of the Society.

The following table shows the progress and present state of the Society:—

| | Compounders | Annual Subscribers | Mathematical Society | Total Fellows | Associates | Patron | Grand Total |
|---|---|---|---|---|---|---|---|
| December 31, 1891 ... ... | 247 | 367 | 3 | 617 | 47 | 1 | 665 |
| Since elected ... ... ... | +2 | +35 | ... | ... | +4 | ... | ... |
| Deceased ... ... ... ... | −7 | −11 | −2 | ... | −3 | ... | ... |
| Resigned ... ... ... ... | ... | −11 | ... | ... | ... | ... | ... |
| Names erased ... ... ... | ... | − 5 | ... | ... | ... | ... | ... |
| Removals ... ... ... ... | +2 | − 2 | ... | ... | ... | ... | ... |
| December 31, 1892 ... ... | 244 | 373 | 1 | 618 | 48 | 1 | 667 |

*Dr. Common's Account as Treasurer of the Royal*

RECEIPTS.

| | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|
| Balances, 1892 January 1:— | | | | | | |
| At Bankers', on current account ... ... | 243 | 17 | 6 | | | |
| ,, on deposit ... ... ... | 200 | 0 | 0 | | | |
| In hand of Assistant Secretary on account of Turnor and Horrox Fund ... ... | 7 | 19 | 3 | | | |
| In hand of Assistant Secretary on Petty Cash Account ... ... ... ... | 0 | 7 | 10 | | | |
| | | | | 452 | 4 | 7 |
| Dividends on £13,200 Consols, 2¾ per cent. ... | 353 | 18 | 8 | | | |
| ,, on £650 New 2½-per-cent. Stock. ... | 11 | 19 | 4 | | | |
| ,, on £1,250 Metropolitan 3 per cent. Stock | 36 | 11 | 4 | | | |
| Interest on Money on deposit at Bankers' ... ... | 0 | 2 | 1 | | | |
| | | | | 402 | 11 | 5 |
| Received on account of Subscriptions:— | | | | | | |
| Arrears ... ... ... ... ... ... | 167 | 8 | 0 | | | |
| 262 Annual Contributions for 1892 ... ... | 550 | 4 | 0 | | | |
| 5 ,, ,, 1893 ... ... | 10 | 10 | 0 | | | |
| 30 Admission Fees ... ... ... ... | 63 | 0 | 0 | | | |
| 28 First Contributions ... ... ... ... | 50 | 8 | 0 | | | |
| | | | | 841 | 10 | 0 |
| 4 Composition Fees ... ... ... ... | | | | 84 | 0 | 0 |
| Sales of Publications:— | | | | | | |
| At Williams & Norgate's, 1891 ... ... | 25 | 12 | 2 | | | |
| At Society's Rooms, 1892 ... ... ... | 43 | 18 | 9 | | | |
| | | | | 69 | 10 | 11 |

Audited and found correct, 1893, January 10.

THOMAS LEWIS,
HAROLD SEWARD.

£1,849 16 11

*Astronomical Society, from* 1892 *January* 1 *to December* 31.

EXPENDITURE.

| | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|
| Assistant Secretary: Salary ... ... ... | 250 | 0 | 0 | | | |
| „ „ for assistance in editing Society's Publications ... | 50 | 0 | 0 | | | |
| | | | | 300 | 0 | 0 |
| Income Tax and House Duty ... ... ... | 10 | 10 | 0 | | | |
| Fire Insurance ... ... ... ... ... | 7 | 16 | 6 | | | |
| | | | | 18 | 6 | 6 |
| Printing, &c. ... ... ... ... ... ... | 526 | 4 | 6 | | | |
| Engraving and Lithography, &c. ... ... ... | 20 | 7 | 4 | | | |
| | | | | 546 | 11 | 10 |
| Turnor and Horrox Fund: Purchases for Library | 7 | 14 | 9 | | | |
| Binding Books in Library ... ... ... ... | 27 | 10 | 10 | | | |
| | | | | 35 | 5 | 7 |
| Lantern for Evening Meetings—Additional Apparatus, &c. ... ... ... ... ... ... | 25 | 15 | 6 | | | |
| Gas-fittings for Lantern ... ... ... ... | 2 | 0 | 0 | | | |
| Oxygen ... ... ... ... ... | 0 | 13 | 6 | | | |
| Lantern Attendant ... ... ... ... ... | 4 | 0 | 0 | | | |
| | | | | 32 | 9 | 0 |
| Decorating ... ... ... ... ... ... | 9 | 15 | 6 | | | |
| Sundry Fittings and Repairs ... ... ... | 13 | 16 | 6 | | | |
| | | | | 23 | 12 | 0 |
| Barometer ... ... ... ... ... ... | | | | 5 | 0 | 0 |
| Copying Press ... ... ... ... ... | 7 | 3 | 6 | | | |
| Stationery and Office Expenses ... ... ... | 15 | 9 | 0 | | | |
| | | | | 22 | 12 | 6 |
| House Expenses ... ... ... ... ... | 57 | 1 | 6 | | | |
| Wages ... ... ... ... ... ... | 40 | 12 | 6 | | | |
| Postage ... ... ... ... ... ... | 68 | 3 | 2 | | | |
| Carriage of Parcels ... ... ... ... ... | 2 | 8 | 11 | | | |
| Expenses of Meetings ... ... ... ... | 21 | 18 | 4 | | | |
| Coals and Gas ... ... ... ... ... | 38 | 10 | 3 | | | |
| Electric Light Expenses ... ... ... ... | 1 | 3 | 8 | | | |
| Rental of Wire for Time Signal, &c. ... ... | 5 | 18 | 0 | | | |
| Care of Fire-extinguishing Apparatus ... ... | 1 | 10 | 11 | | | |
| Sundries ... ... ... ... ... ... | 5 | 7 | 5 | | | |
| | | | | 242 | 14 | 8 |
| Mrs. Jackson Gwilt's Annuity ... ... ... | 8 | 19 | 0 | | | |
| Lee and Janson Fund Grants ... ... ... | 15 | 0 | 0 | | | |
| | | | | 23 | 19 | 0 |
| Purchase of £237 10 10 New 2½-per-cent. Stock at 93⅝, including Commission ... ... ... | 222 | 14 | 5 | | | |
| Purchase of £200 New 2½-per-cent. Stock, at 96¼, including Commission ... ... ... ... | 192 | 15 | 6 | | | |
| | | | | 415 | 9 | 11 |
| Deductions on Cheques ... ... ... ... | | | | 0 | 4 | 0 |
| Balances, 1892 December 31:— | | | | | | |
| At Bankers', as per Pass Book ... ... | 163 | 16 | 0 | | | |
| Country Cheques not Credited till 1893 ... | 8 | 8 | 0 | | | |
| In hand of Assistant Secretary on account of Turnor and Horrox Fund ... ... | 10 | 4 | 6 | | | |
| In hand of Assistant Secretary on Petty Cash Account ... ... ... ... | 1 | 3 | 5 | | | |
| | | | | 183 | 11 | 11 |
| | | | | £1,849 | 16 | 11 |

*Assets and Present Property of the Society, 1893 January 1.*

| | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|
| Balances in hand, December 31, 1892:— | | | | | | |
| At Bankers', as per pass book ... ... ... | 163 | 16 | 0 | | | |
| Country Cheques not credited till 1893 ... | 8 | 8 | 0 | | | |
| In hand of Assistant Secretary on account of Turnor and Horrox Fund ... ... | 10 | 4 | 6 | | | |
| In hand of Assistant Secretary on Petty Cash Account ... ... ... ... ... | 1 | 3 | 5 | | | |
| | | | | 183 | 11 | 11 |
| Due on account of Subscriptions:— | | | | | | |
| 1 Contribution of 5 years' standing ... ... | 10 | 10 | 0 | | | |
| 10 Contributions of 3 ,, ... ... | 63 | 0 | 0 | | | |
| 35 ,, 2 ,, ... ... | 147 | 0 | 0 | | | |
| 46 ,, 1 ,, ... ... | 96 | 12 | 0 | | | |
| 7 Admission Fees and 1st Contributions ... | 22 | 1 | 0 | | | |
| Other Amounts ... ... ... ... | 7 | 7 | 0 | | | |
| | 346 | 10 | 0 | | | |
| Less 5 Contributions paid in advance ... | 10 | 10 | 0 | | | |
| | | | | 336 | 0 | 0 |
| Due from Messrs. Williams & Norgate on account of sales of Publications, 1892 ... ... ... ... ... ... | | | | 37 | 11 | 6 |
| Due from Messrs. Wesley & Son, from sale of old non-astronomical books ... ... ... ... ... ... ... | | | | 5 | 19 | 9 |
| £13,200 $2\frac{3}{4}$-per-cent. Consols, including the Lee and Janson Fund, the Turnor Fund, the Horrox Memorial Fund, and Mrs. Jackson Gwilt's gift. | | | | | | |
| £650 New $2\frac{1}{2}$-per-cent. Consols. | | | | | | |
| £1,250 Metropolitan 3-per-cent. Stock. | | | | | | |
| Astronomical and other Manuscripts, Books, Prints, and Instruments; Furniture, &c. | | | | | | |
| Unsold Publications of the Society. | | | | | | |
| 4 Gold Medals. | | | | | | |

### *Trust Funds.*

*The Turnor Fund*: A sum of £450 2¾-per-cent. Consols, the interest to be used in the purchase of books for the Library.

*The Horrox Memorial Fund*: A sum of £100 2¾-per-cent. Consols, the interest to be used in the purchase of books for the Library.

*The Lee and Janson Fund*: A sum of £323 16*s.* 3*d.* 2¾-per-cent. Consols, the interest to be given by the Council to the widow or orphan of any deceased Fellow or Associate of the Society who may stand in need of it.

*Mrs. Jackson Gwilt's Gift*: A sum of £300 2¾-per-cent. Consols, subject to an annuity to the donor, during her life, of £8 19*s.* per annum.

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### *Report of the Auditors.*

We have examined the Treasurer's accounts for the year 1892, and have found and certified the same to be correct. The cash in hand on December 31, 1892, including the balance at the bankers', &c., amounted to £183 11*s.* 11*d.*

The funded property of the Society has been increased by the purchase of £437 10*s.* 10*d.* New 2½-per-cent. stock.

The books, instruments, and other effects have been examined, and they appear to be in a satisfactory condition. Some instruments belonging to the Society appear to have been lent for a considerable number of years: we think it desirable that a renewed acknowledgment should in such cases be given for these.

We have laid on the table a list of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting, with the amount due against each Fellow's name.

(Signed) Thomas Lewis,
Harold Seward.

Stock in hand of volumes of the *Memoirs*:—

| Vol. | At Society's Rooms | At Williams & Norgate's | Vol. | At Society's Rooms | At William & Norgate's |
|---|---|---|---|---|---|
| I. Part 1 | 7 | ... | XXX. | 156 | ... |
| I. Part 2 | 42 | ... | XXXI. | 139 | ... |
| II. Part 1 | 54 | ... | XXXII. | 151 | ... |
| II. Part 2 | 20 | ... | XXXIII. | 160 | 1 |
| III. Part 1 | 65 | 1 | XXXIV. | 162 | 3 |
| III. Part 2 | 84 | 1 | XXXV. | 107 | 5 |
| IV. Part 1 | 77 | 3 | XXXVI. | 195 | 8 |
| IV. Part 2 | 90 | 3 | XXXVII. Part 1 | 336 | 8 |
| V. | 102 | 3 | XXXVII. Part 2 | 282 | 8 |
| VI. | 123 | 3 | XXXVIII. | 267 | 1 |
| VII. | 142 | 3 | XXXIX. Part 1 | 236 | 1 |
| VIII. | 126 | 3 | XXXIX. Part 2 | 241 | 3 |
| IX. | 133 | 3 | XL. | 258 | 1 |
| X. | 143 | ... | XLI. | 406 | 1 |
| XI. | 152 | ... | XLII. | 232 | 3 |
| XII. | 159 | ... | XLIII. | 235 | 1 |
| XIII. | 159 | ... | XLIV. | 214 | 1 |
| XIV. | 365 | ... | XLV. | 246 | ... |
| XV. | 137 | ... | XLVI. | 227 | 1 |
| XVI. | 163 | 1 | XLVII. Part 1 | 3 | ... |
| XVII. | 146 | 1 | XLVII. Part 2 | 18 | ... |
| XVIII. | 143 | 1 | XLVII. Part 3 | 2 | ... |
| XIX. | 147 | 1 | XLVII. Part 4 | 10 | ... |
| XX. | 139 | 1 | XLVII. Part 5 | 8 | ... |
| XXI. Part 1 | 312 | ... | XLVII. Part 6 | 9 | ... |
| XXI. Part 2 | 98 | ... | XLVII. | 202 | 2 |
| XXI. 1 & 2 (together) | 59 | 1 | XLVIII. Part 1 | 246 | 2 |
| XXII. | 161 | 1 | XLVIII. Part 2 | 255 | 2 |
| XXIII. | 145 | 1 | XLIX. Part 1 | 450 | 1 |
| XXIV. | 153 | 1 | XLIX. Part 2 | 317 | 1 |
| XXV. | 163 | ... | L. | 385 | 4 |
| XXVI. | 174 | 1 | Index to *Memoirs* | 638 | 1 |
| XXVII. | 421 | 1 | | | |
| XXVIII. | 380 | 1 | | | |
| XXIX. | 402 | ... | | | |

Stock in hand of volumes of the *Monthly Notices* :—

| Vol. | At Society's Rooms | At Williams & Norgate's | Vol. | At Society's Rooms | At Williams & Norgate's |
|---|---|---|---|---|---|
| I. | 63 | ... | XXVIII. | 71 | ... |
| II. | 65 | ... | XXIX. | 51 | ... |
| III. | ... | ... | XXX. | 64 | 2 |
| IV. | ... | ... | XXXI. | 92 | ... |
| V. | ... | ... | XXXII. | 115 | 5 |
| VI. | 50 | ... | XXXIII. | 97 | ... |
| VII. | 2 | ... | XXXIV. | 75 | 1 |
| VIII. | 153 | 2 | XXXV. | 54 | ... |
| IX. | 24 | 3 | XXXVI. | 30 | 1 |
| X. | 178 | 1 | XXXVII. | 37 | 3 |
| XI. | 184 | ... | XXXVIII. | 100 | 2 |
| XII. | 106 | 2 | XXXIX. | 97 | 1 |
| XIII. | 178 | 2 | XL. | 110 | 3 |
| XIV. | 177 | 3 | XLI. | 110 | 5 |
| XV. | 169 | 2 | XLII. | 120 | 1 |
| XVI. | 154 | 1 | XLIII. | 116 | 2 |
| XVII. | 167 | 1 | XLIV. | 119 | 2 |
| XVIII. | 244 | ... | XLV. | 121 | ... |
| XIX. | 56 | ... | XLVI. | 116 | ... |
| XX. | 30 | ... | XLVII. | 134 | 4 |
| XXI. | 17 | ... | XLVIII. | 126 | 2 |
| XXII. | 33 | ... | XLIX. | 120 | 10 |
| XXIII. | 19 | ... | L. | 123 | 13 |
| XXIV. | 24 | ... | LI. | 134 | 11 |
| XXV. | 15 | ... | LII. | 124 | 15 |
| XXVI. | 11 | ... | Index ... | 564 | 3 |
| XXVII. | 4 | ... | | | |

Library Catalogue ... ... ... ... ... ... 570

In addition to the above volumes of the *Monthly Notices*, the Society has a considerable stock of separate numbers of nearly all the volumes. With the exception, however, of Vols. XXXVI. to LII., no complete volumes can be formed from the separate numbers in stock.

*Instruments belonging to the Society.*

No. 1. The *Harrison* clock.
,, 2. The *Owen* portable circles, by Jones.
,, 3. The *Beaufoy* circle.

No. 4. The *Beaufoy* transit instrument.
,, 5. The *Herschel* 7-foot telescope.
,, 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Utzschneider and Fraunhofer, of Munich.
,, 7. The *Smeaton* equatoreal.
,, 8. The *Cavendish* apparatus.
,, 9. The 7-foot Gregorian telescope (late Mr. Shearman's).
,, 10. The variation transit instrument (late Mr. Shearman's).
,, 11. The universal quadrat, by Abraham Sharp.
,, 12. The *Fuller* theodolite.
,, 13. The standard scale, by Troughton and Simms.
,, 14. The *Beaufoy* clock, No. 1.
,, 15. The *Beaufoy* clock, No. 2.
,, 16. The *Wollaston* telescope.
,, 17. The *Lee* circle.
,, 18. The *Sharpe* reflecting circle.
,, 19. The *Brisbane* circle.
,, 20. The *Baker* universal equatoreal.
,, 21. The *Reade* transit.
,, 22. The *Matthew* equatoreal, by Cooke.
,, 23. The *Matthew* transit instrument.
,, 24. The *South* transit instrument.
,, 25. A sextant, by Bird (formerly belonging to Captain Cook).
,, 26. A globe showing the precession of the equinoxes.
The *Sheepshanks* collection :—
,, 27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.
,, 28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumb-line; portable clamping foot and tripod stand.
,, 29. (3) Equatorial stand and clock movement for $4\frac{6}{10}$-inch telescope (telescope lost); double-image micrometer; two wire micrometers; object-glass micrometer.
,, 30. (4) $3\frac{1}{4}$-inch achromatic telescope, with equatorial stand; double-image micrometer; one terrestrial and three astronomical eyepieces.
,, 31. (5) $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.
,, 33. (7) 2-foot navy telescope.
,, 34. (8) Transit instrument of 45 inches focal length, with iron stand and also Ys for fixing to stone piers; two axis levels.
,, 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.

No. 36. (10) 8-inch pillar sextant, by Troughton, divided on platinum, with counterpoise stand and artificial horizon.

„ 37. (11) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, read to 10″ by two verniers to each circle.

„ 38. (12) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{8}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

„ 39. (13) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye-end, reading to single minutes; horizontal circle 9 inches diameter in brass, reading to single minutes.

„ 40. (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; heavy stand for theodolite; Y piece of level; two large and three small ground-glass bubbles divided; level collimator, object-glass $1\frac{5}{8}$-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.

„ 41. (15) Level collimator, with object-glass $1\frac{7}{8}$-inch diameter and 16 inches focal length; stand, rider-level, and fittings.

„ 42. (16) 10-inch reflecting circle by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon, with mercury; two tripod stands.

„ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. Circle divided on silver, reading to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

„ 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.

„ 46. (20) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.

„ 47. (21) Box sextant; reflecting plane and level.

„ 48. (22) Prismatic compass, by Troughton and Simms.

„ 49. (23) Mountain barometer.

„ 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.

No. 51. (25) Ordinary $4\frac{1}{2}$-inch compass with needle.
„ 52. (26) Dipping needle, by Robinson.
„ 53. (27) Compass needle, mounted for variation.
„ 54. (28) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.
„ 55. (29) Box of magnetic apparatus.
„ 56. (30) Hassler's reflecting circle, by Troughton; a $10\frac{1}{2}$-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10″.
„ 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.
„ 58. (32) Plane $2\frac{3}{8}$-inch speculum, artificial horizon, and stand.
„ 59. (33) $2\frac{1}{2}$-inch circular level horizon, by Dollond.
„ 60. (34) Artificial horizon, roof, and trough; the trough $8\frac{1}{4}$ by $4\frac{1}{2}$ inches; tripod stand.
„ 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square; one beam compass.
„ 62. (36) A pantograph.
„ 63. (37) A noddy.
„ 64. (38) A small Galilean telescope with object-glass of rock crystal.
„ 65. (39) Five levels.
„ 66. (40) 18-inch celestial globe.
„ 67. (41) Varley stand for telescope.
„ 69. (43) Telescope, with object-glass of rock crystal.
„ 71. Portable altazimuth tripod.
„ 72. Four polarimeters.
„ 74. Registering spectroscope, with one large prism.
„ 76. Two five-prism direct-vision spectroscopes.
„ 78. $9\frac{1}{4}$-inch silvered-glass reflector and stand, by Browning.
„ 79. Spectroscope.
„ 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.
„ 81. A back-staff, or Davis' quadrant.
„ 82. A nocturnal or star dial.
„ 83. An early non-achromatic telescope, of about 3 feet focal length, in oak tube, by Samuel Scatliffe, London.
„ 84. A Hollis observing chair.
„ 85. Double-image micrometer, by Troughton and Simms.
„ 86. $4\frac{1}{2}$-inch Gregorian reflecting telescope, by Short, with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.

No. 87. $3\frac{1}{4}$-inch Gregorian reflecting telescope with wooden tripod stand.
„ 88. Pendulum, with 5-foot brass suspension rod, working on knife-edges, by Thomas Jones.
„ 89. A Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box filled with compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.
„ 90. An Arabic celestial globe of bronze, $5\frac{3}{4}$ inches in diameter.
„ 91. Astronomical time watchcase, by Professor Chevallier.
„ 92. 2-foot protractor, with two movable arms, and vernier.
„ 93. Beam compass, in box.
„ 94. 2-foot navigation scale.
„ 95. Stand for testing measures of length.
„ 96. Artificial planet and star, for testing the measurement of a fixed distance at different position-angles.
„ 97. 12-cell Leclanché battery.
„ 98. 2-foot 6-inch navy telescope, with object-glass $2\frac{1}{2}$ inches, by Cooke, with portable wooden tripod stand.
„ 99. 12-inch transit instrument, by Fayrer and Son, with level and portable stand.
„ 100. 9-inch transit instrument, with level and iron stand.
„ 101. Small equatorial sight instrument, by G. Adams, London.
„ 102. Sun-dial, by Troughton.
„ 103. Sun-dial, by Casella.
„ 104. Sun-dial.
„ 105. Box sextant, by Troughton and Simms.
„ 106. Prismatic compass, by Schmalcalder, London.
„ 107. Compass, by C. Earle, Melbourne.
„ 108. Prismatic compass, by Negretti and Zambra.
„ 109. Dipleidoscope, by E. Dent.
„ 110. Abney level, by Elliott.
„ 111. Pocket spectroscope, by Browning.
„ 112. Universal sun-dial.
„ 113. Double sextant, by Jones.
„ 114. Two models, illustrating the effects of circular motions.
„ 115. A cometarium.
„ 116. A pair of 18-inch globes.
„ 117, „ 118. Two old sun-dials.

No. 119. Specimens of diffraction gratings, by Prof. W. A. Rogers.
,, 120. A 6-prism spectroscope, by Browning.
,, 121. Spitta's improved maximum and minimum thermometer.
,, 122. A 6-inch speculum, with flat; the speculum said to be by Sir W. Herschel, and re-figured by Sir J. Herschel.
,, 123. A 6-inch refracting telescope, by Grubb, with 3 eyepieces.
,, 124. Position micrometer, by Cooke.
,, 125. A 6-inch refracting telescope, by Simms, with eyepieces and solar diagonal.
,, 126. $3\frac{1}{2}$-in. portable refracting telescope, by Tulley, with tripod stand.
,, 127. Globe representing the visible surface of the Moon, by John Russell, R.A. (1797).
,, 128. Bichromate battery and Ruhmkorff coil.
,, 129. Slater's improved armillary sphere, presented by Prof. Slater.

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons :—

No. 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.
,, 10. Variation transit, to Mr. Maxwell Hall.
,, 16. The *Wollaston* telescope, to Mr. R. Inwards.
,, 22. The *Matthew* equatoreal, to Mr. J. Brett.
,, 23. The *Matthew* transit, to Captain W. Noble.
,, 28. (2) 6-inch theodolite and stand, to Dr. A. A. Common.
,, 29. (3) Wire micrometer (No. 1), to Mr. C. Thwaites.
,, ,, ,, Wire micrometer (No. 2), to Mr. Maxwell Hall.
,, 30. (4) $3\frac{1}{4}$-inch equatoreal and stand, to Mr. E. B. Powell.
,, ,, ,, Double-image micrometer, to Mr. Maxwell Hall.
,, 31. (5) $2\frac{3}{4}$-inch telescope and stand, to Mr. F. J. Wardale.
,, 34. (8) Transit instrument and stand, to Professor C. Pritchard.
,, 38. (12) 18-inch *Borda* repeating circle, to Mr. Maxwell Hall.
,, 39. (13) 8-inch repeating circle, to Mr. J. Norman Lockyer.
,, 42. (16) Artificial horizon, roof, and mercury bottle, to Mr. C. Thwaites.
,, 50. (24) Prismatic compass, to Mr. Maxwell Hall.
,, 52. (26) Dipping needle, to Mr. Maxwell Hall.
,, 54. (28) Magnetic intensity needle, to Mr. Maxwell Hall.
,, 69. (43) Telescope, with rock-crystal object-glass, to Dr. W. Huggins.
,, 74. Registering spectroscope, to Mr. John Mitchell.
,, 78. $9\frac{1}{4}$-inch reflector and stand, to Mr. Maxwell Hall.

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| No. 79. | Spectroscope, to Mr. Maxwell Hall. |
| „ 92. | $2\frac{1}{2}$-inch navy telescope, to Mr. M. D. Severn. |
| „ 99. | 12-inch portable transit instrument, to Mr. H. T. Vivian. |
| „ 120. | 6-prism spectroscope, by Browning, to Mr. C. Thwaites. |
| „ 123. | 6-inch refractor, by Grubb, with three eyepieces, to Mr. W. E. Wilson. |
| „ 124. | Position micrometer, by Cooke, to the Rev. A. Freeman. |
| „ 125. | One dark wedge, to the Rev. A. Freeman. |
| „ 126. | $3\frac{1}{2}$-inch portable refractor, by Tulley, to Mr. H. Sadler. |

*The Gold Medal.*

The Council have awarded the Society's Gold Medal to Professor H. C. Vogel for his Spectroscopic and other Astronomical Observations.

*Publications of the Society.*

Volume L. of the *Memoirs* has been published during the past year; it contains the following papers:—

"Fifth Catalogue of Micrometrical Measures of Double Stars made at the Temple Observatory, Rugby." By G. M. Seabroke, A. P. Smith, and H. P. Highton.

"Observations of the Spectra of Sun-spots in the Region B—D made at the Stonyhurst College Observatory." By the Rev. A. L. Cortie.

"Measures of Double Stars made at Sydney Observatory in the years 1882–89." Communicated by H. C. Russell.

"Double-star Observations, 1888–91." By W. H. Maw.

"On the Construction of a Five-foot Equatorial Reflecting Telescope." By A. A. Common.

The attention of foreign and American astronomers is requested to the following paragraph in the Report of the Council for 1879. It is against the rules of the Society to print any paper previously published:—

"The Council hope that the communication between English and foreign astronomers will continue to increase, but they take this opportunity of mentioning that some of the papers which have been received by the Society have not been printed on account of their having been previously published abroad."

## Obituary.

The Council regret that they have to record the loss by death of the following Fellows and Associates during the past year:—

Fellows:—Rev. Edward Allen.
Robert Grant.
John Hartnup.
Thomas Archer Hirst.
Joseph Kleiber.
Benjamin Loewy.
W. Edwards Michell.
Rev. I. Vale Mummery.
A. V. Nursing Row.
Captain G. C. Parker.
Charles Greville Prideaux.
Rev. Joseph Spear.
Thomas Taylor.
George Turnbull.
W. Mattieu Williams.

Associates:—Annibale de Gasparis.
Admiral E. Mouchez.
Lewis M. Rutherfurd.

John Couch Adams was born on June 5, 1819, at the farm-house of Lidcot, seven miles from Launceston, in Cornwall. His father was a tenant farmer, and his mother possessed a small estate of land of her own. She had also inherited her uncle's library, and these books, which included some on astronomy, were his early companions. At the village school at Laneast he made rapid progress, and was learning algebra before he was twelve years old. At this age he went to a private school at Devonport, kept by the Rev. John Couch Grylls, a first cousin of his mother.

He remained under Mr. Grylls's tuition for a good many years, first at Devonport and afterwards at Saltash and Landulph, and received the usual school training in classics and mathematics. Astronomy had been his passion from very early boyhood, and at fourteen years of age he made copious notes and drew tiny maps of the constellations. He read with avidity all the astronomical books to which he could obtain access, and in particular he studied the astronomical articles in Rees's

"Cyclopædia," which he met with in the library of the Devonport Mechanics' Institute, where he used to spend his spare time in reading astronomy and mathematics. In the same library he came across a copy of Vince's "Fluxions," which was his first introduction to the higher mathematics.

He showed such signs of mathematical power that in 1837 the idea of his going to Cambridge was entertained. He accordingly entered St. John's College, Cambridge, in October 1839. During his undergraduate career he was invariably the first man of his year in the college examinations, and in 1843 he graduated as Senior Wrangler, being also first Smith's Prizeman. In the same year he was elected Fellow of his college.

His attention was drawn to the irregularities in the motion of *Uranus* by reading Airy's report upon recent progress in astronomy in the British Association volume for 1831–32,* and on July 3, 1841, he made the following memorandum:— "Formed a design at the beginning of this week of investigating, as soon as possible after taking my degree, the irregularities in the motion of *Uranus* which are yet unaccounted for, in order to find whether they may be attributed to the action of an undiscovered planet beyond it; and, if possible, thence to determine the elements of its orbit &c. approximately, which would probably lead to its discovery." This memorandum was made at the beginning of his second long vacation, when he was in his twenty-third year.†

In 1843, the year in which he took his degree, he attempted a first rough solution of the problem on the assumption that the orbit was a circle with a radius equal to twice the mean distance of *Uranus* from the Sun. The result showed that a good general agreement between theory and observation might be obtained. In order to make the data employed more complete application was made through Professor Challis to the Astronomer Royal for the results of the Greenwich observations of *Uranus*. When these were obtained Adams undertook a new solution of the problem, taking into account the most important terms depending on the first power of the eccentricity of the orbit of the supposed disturbing planet, but retaining the same assumption as before with respect to the mean distance. In September, 1845, he communicated to Professor Challis the values which he had obtained for the mass, heliocentric longitude, and elements of the orbit of the assumed planet. The same results, slightly corrected, he took with him to the Royal Observatory, Greenwich, on October 21, 1845. The paper which he left at the Observatory on this occasion also contained a list

* This report does not contain any reference to the irregularities being possibly due to an exterior planet. It is merely mentioned that it seems impossible to unite all the observations in one elliptic orbit, and that Bouvard was therefore obliged to reject the ancient observations entirely (p. 154).

† The original memorandum, written by itself on a slip of paper, has been found among his papers since his death.

of the residual errors of the mean longitude of *Uranus*, after taking account of the disturbing effect of the new planet, at dates extending from 1690 to 1840.

On November 10, 1845, Le Verrier presented to the French Academy an elaborate investigation of the perturbations of *Uranus* produced by *Jupiter* and *Saturn*, in which he pointed out several small inequalities which had previously been neglected. After taking these into account, and correcting the elements of the orbit, he still found that the theory was quite incapable of explaining the observed irregularities in the motion of *Uranus*.

On June 1, 1846, Le Verrier presented to the French Academy his second memoir on the theory of *Uranus*, in which he concluded that the unexplained irregularities in the motion of *Uranus* were due to the action of an undiscovered planet exterior to *Uranus*. He investigated the elements of the orbit of such a planet, and, assuming its mean distance to be double that of *Uranus*, and its orbit to be in the plane of the ecliptic, he found that the most probable value of the true longitude of the disturbing body for the beginning of 1847 was about 325°, but he did not give the elements of the orbit or the mass of the planet.

The place thus assigned by Le Verrier to the disturbing planet differed by only 1° from that given by Adams in the paper which he had left at the Greenwich Observatory seven months earlier. Le Verrier's third memoir, in which he gave the elements of the orbit, was communicated to the French Academy on August 31, 1846.

Professor Challis commenced the search for the planet with the Northumberland telescope of the Cambridge Observatory on July 29, 1846, three weeks before the planet was in opposition, and the observations were continued for two months. His plan was to examine a zodiacal zone having its centre in the ecliptic at 325° of longitude, and extending 15° of longitude in each direction from the central point, and from 5° north latitude to 5° south latitude. He proposed to make two sweeps over each portion of the zone, so that, when the observations were compared, a planet could be at once detected by its motion in the interval. For the first few nights the telescope was directed to the part of the zone in the immediate neighbourhood of the place indicated by theory. Unfortunately the observations were not immediately compared with each other, or Professor Challis would have discovered, what he found afterwards to be the case, that he had actually observed the planet on August 4 and August 12, the third and fourth nights of observation. The star-map of the Berlin Academy for Hora xxi. of right ascension had lately been published, but the English astronomers were not aware of its existence. By the help of this map the search would have been extremely easy and rapid, as the observations could have been compared with the map as fast as they were made.

On September 3, 1846, Adams communicated to the Astro-

nomer Royal a new solution of the problem, supposing the mean distance of the planet as originally assumed to be diminished by about the $\frac{1}{30}$th part. The result of this change was to produce a better agreement between the theory and the later observations, and to give a smaller and therefore a more probable value of the eccentricity. Meanwhile, on August 3, 1846, Le Verrier had presented to the French Academy his second paper upon the place of the disturbing planet, which, however, did not reach this country till the third or fourth week in September. In this elaborate paper Le Verrier obtained elements of the orbit of the disturbing planet, which are very similar to those obtained in Adams's second solution. Le Verrier communicated his principal conclusions to Dr. Galle, of the Berlin Observatory, in a letter received by him on September 23, 1846, and, by comparing his observations with the Berlin star-map, Dr. Galle found the planet on the same evening.

Adams's researches, therefore, preceded Le Verrier's by a considerable interval; and, in spite of the delay in commencing the search, it had been carried on at Cambridge for nearly two months before the planet was found at Berlin. Adams's investigation may be regarded as having been completed on October 21, 1845, when he left his paper at the Royal Observatory. This was three weeks before Le Verrier's memoir, showing that the irregularities could not be attributed to the known planets, was presented to the French Academy, and more than seven months before the date of presentation of his second memoir. As we know, Adams had resolved to undertake the work in 1841, and his first solution was effected, as soon as he had leisure, in 1843. We may presume that Le Verrier did not attempt the actual solution until after the completion of his memoir of November 10, 1845.

The discovery of the actual planet by Dr. Galle, in consequence of Le Verrier's prediction, was received with the most unbounded enthusiasm by astronomers of all countries, and the planet was at once called *Le Verrier's Planet.* Adams's work was only known to Airy, Challis, and a few other persons, chiefly private friends. The first public mention of his name occurred in a letter written by Sir J. Herschel on October 1, which appeared under the heading "Le Verrier's Planet" in the *Athenæum* for October 3, 1846. He refers to the address he had delivered on September 10, on the occasion of resigning the Presidential Chair of the British Association at Southampton, in which, after referring to the astronomical events of the year, among which was included the discovery of a new planet, he added the words—"It has done more. It has given us the probable prospect of the discovery of another. We see it as Columbus saw America from the shores of Spain. Its movements have been felt, trembling along the far-reaching line of our analysis, with a certainty hardly inferior to that of ocular demonstration."

To justify the confidence which these words express, Herschel first describes a conversation with Bessel in 1842, in which the latter had said that it was highly probable that the deviations of *Uranus* might be due to an unknown planet (being systematic, and such as an exterior planet would produce), and then proceeds :—

"The remarkable calculations of M. Le Verrier, which have pointed out, as now appears, nearly the true situation of the new planet by resolving the inverse problem of the perturbations—if uncorroborated by repetition of the numerical calculations by another hand, or by independent investigation from another quarter—would hardly justify so strong an assurance as that conveyed by my expressions above alluded to. But it was known to me at that time (I will take the liberty to cite the Astronomer Royal as my authority) that a similar investigation had been independently entered into, and a conclusion as to the situation of the new planet very nearly coincident with M. Le Verrier's arrived at (in entire ignorance of his conclusions) by a young Cambridge mathematician, Mr. Adams, who will, I hope, pardon this mention of his name (the matter being one of great historical moment), and who will, doubtless in his own good time and manner, place his calculations before the public."

This passage seems to have passed almost unnoticed, however, in the outburst of enthusiasm with which Le Verrier's discovery was hailed, and it was not till October 17, when a letter from Challis appeared in the *Athenæum*, giving an account of the circumstances, that attention was directed to Adams's calculations. It was then for the first time known that his conclusions had been in the hands of the Astronomer Royal and Challis since 1845, and that the latter had actually been engaged in searching for the planet. There was naturally a disinclination to give full credit to facts thus suddenly brought to light at such a time. It was startling to realise that the Astronomer Royal had had in his possession the data which would have enabled the planet to have been discovered nearly a year before. On the other hand, it seemed extraordinary that a competent mathematician, who had determined the orbit of the disturbing planet, should have been content to refrain for so long from making public his results. No time was now lost in bringing the evidence before the world. On November 13, 1846, Airy communicated to the Society an "Account of some Circumstances historically connected with the Discovery of the Planet exterior to *Uranus*"; and Challis also described the observations which he had undertaken in search of the planet. At the same meeting Adams communicated a memoir containing an account of his mathematical investigations in connection with the determination of the mass, orbit, and position of the new planet, by which he had obtained the elements communicated to the Astronomer Royal on October 21, 1845, and September 3, 1846. All of these papers are published in vol. xvi. of the *Memoirs*; but as it was felt that the immediate publication and circulation of Adams's memoir was a

matter of national interest, it was at once printed separately by Lieut. Stratford, superintendent of the *Nautical Almanac* Office, as a special appendix to the *Nautical Almanac* for 1851, and widely circulated at the beginning of 1847. This appendix was also circulated as a supplement to No. 593 (1847 March 2) of the *Astronomische Nachrichten*. It is not necessary here to discuss the question whether blame can fairly be laid to the charge of Airy or any of the other persons concerned. There is, fortunately, no dispute whatever about the facts, and in a letter to Sheepshanks, which is in the possession of the Society, Adams expressed himself as quite satisfied with Airy's statement of the case. It is perfectly true that Adams, as was said at the time, conducted himself more like a "bashful boy" than an investigator who had made a magnificent discovery. It is also true that he did not reply to an inquiry of Airy's, thinking it trivial. On the other hand, we are met by Airy's apparent indifference to Adams's results in comparison with the enthusiasm with which he greeted Le Verrier's results and prediction, although the honour of the actual discovery might have belonged to this country if he had shown more interest in the researches that had been carried out in his own university.

The French astronomers, especially Arago, were at first very unwilling to admit that Adams had any right whatever in connection with the planet, either as an independent discoverer or otherwise. Strange as it may seem, this view was also taken by some English astronomers, who, giving full credit to Le Verrier, denied all merit to Adams. It was contended that the fact that Adams's results had not been announced publicly, but had been merely communicated to the Astronomer Royal and a few others, deprived him of all claims in relation to the discovery. As has been stated, Adams himself, immediately after the finding of the planet, wrote out his investigations and submitted them to the Society; but neither then nor at any subsequent time did he take any part in the discussion himself, nor did he ever write or speak an unfriendly word with respect to anyone concerned in it. In France a very fair view of the matter was taken by Biot, and in England the speedy recognition of the merits of Adams's researches was mainly due to the warm and generous advocacy of two Cambridge men—Sedgwick and Sheepshanks, the latter of whom was at that time Secretary of the Society and Editor of the *Monthly Notices*.*

* In an interesting letter to Schumacher, now in the possession of the Society, Sheepshanks wrote as follows, under date April 7, 1847:—"You will be surprised when I tell you that the *strongest* opponents to Mr. Adams's claims to consideration are to be found in England, of course with the exception of France. All acknowledge M. Le Verrier's merits, and all admit his *undoubted* claim to *independent* discovery. All are agreed, too, that in *making public his results and investigations* in the masterly and confident way he did, he deserves the highest praise. As to *national* feeling (which, by the way, is too often national injustice) there is absolutely none whatever, so far as I know, or

The Royal Society at once awarded their highest honour, the Copley Medal, to Le Verrier (1846), and it was not till two years afterwards that it was awarded to Adams. Our Society was saved from expressing a similar preference by the bye-law requiring that the award of the medal should be confirmed by a majority of three-quarters of the Council. A sufficient minority were of opinion that "an award to M. Le Verrier, unaccompanied by another to Mr. Adams, would be drawing a greater distinction between the two than fairly represents the proper inference from facts, and would be an injustice to the latter." * It had been proposed that the General Meeting should be recommended to suspend the existing bye-law, so that more than one medal might be given, but the proposal was not carried on the Council. No medal of the Society has been awarded in connection with the discovery of *Neptune*, either at that time or subsequently.

Looking back now upon Adams's achievement, which, as has been truly said, belongs at once to the science and the romance of astronomy, there are several points that stand out as very remarkable: his extreme youth when he attacked, unaided, so difficult a problem, and steadily carried it through to success; his faith in the Newtonian law and in the results of his own mathematics; and his extreme modesty. As soon as he took his degree in 1843 he devoted his whole leisure, in term time at Cambridge, and in vacations in Cornwall, to the new planet's orbit, without assistance or encouragement from anyone. How quietly and unassumingly he pursued his investigations is shown by the fact that at the time of the finding of the planet his name was only known to Airy, Challis, Herschel,

among astronomers. In England at present the current runs the other way, and though I very much prefer this failing of the two, yet it is provoking too. I assure you that it was with difficulty that one could get a hearing, while pointing out the fact that Mr. Adams had deduced the elements and place of the planet in October 1845. I have been told repeatedly by those who should have known better that this was nothing at all, simply because the over-modest man communicated his results to Airy and Challis, that the planet might be looked for, instead of bringing his investigation before the world as he ought to have done. Surely it is a greater honour to science that two men should independently have come to the same conclusion from the same data than that one should have hit on it, as it were, accidentally. Thanks to Struve and Biot, &c. our anti-Adamites are calmer, and as there never was any opposition to Le Verrier, we are quite satisfied at present, and so I hope are the two discoverers. I think there is a hope that Mr. Adams will continue his astronomical researches. In any other country there could be no doubt of it, but in England there is no *carrière* for men of science. The Law or the Church seizes on all talent which is not independently rich or careless about wealth." The principal contemporary publications relating to the new planet are to be found in vol. xvi. of the *Memoirs*, in the *Comptes Rendus*, in the *Athenæum*, in the *Astronomische Nachrichten*, and in vol. vii. (1847) of the *North British Review*, which contains an article by Brewster. Challis's report of December 12, 1846, to the Observatory Syndicate at Cambridge, which contains an account of his own proceedings relating to the new planet, was published in the *Monthly Notices* for 1883 (vol. xliii. pp. 165–172).

* *Monthly Notices*, vol. vii. p. 216.

Earnshaw, and a few intimate university friends of his own standing. The implicit reliance that he placed in the sufficiency of the Newtonian law to explain all the phenomena of the heavens is also noteworthy, as it was then considered much more likely than it is now that the true law might not be exactly that of the inverse square, or might be subject to other modifications.* He was perfectly convinced of the reality of the planet and of the approximate accuracy of the place he had assigned to it; and in the paper which he placed in the hands of Challis in September, 1845, he used the words "the new planet." It is to be regretted that he should have refrained from publishing his results at the time (which he had been advised to do by some of his Cambridge friends), but he can scarcely be blamed for believing that the course he had taken would lead to a search being made for the planet at Greenwich or elsewhere.

A French translation of the memoir presented to the Society in 1846 was published in Liouville's *Journal de Mathématiques Pures et Appliquées* for 1875. The Editor, M. Résal, stated

* The words in the text were in type before the writer saw a private letter from Adams to Professor James Thomson, dated November 26, 1846, from which the following very interesting sentences relating to this subject are extracted:—"On considering the subject it appeared to me that by far the most probable hypothesis that could be formed to account for these irregularities was that of the existence of an exterior undiscovered planet whose action on *Uranus* produced the disturbances in question. None of the other hypotheses that had been thrown out seemed to possess the slightest claims to attention, as they were all improbable in themselves, and incapable of being tested by any exact calculation. Some had even supposed that, at the great distance of *Uranus* from the Sun, the law of attraction became different from that of the inverse square of the distance, but the law of gravitation was too firmly established for this to be admitted till every other hypothesis had failed to account for the observed irregularities; and I felt convinced that in this, as in all previous instances of the kind, the discrepancies which had for a time thrown doubts on the truth of the law, would eventually afford it the most striking confirmation. In contrast with all these vague hypotheses, the supposition that the irregularities were caused by the action of an unknown planet appeared to be thoroughly in accordance with the present state of our knowledge, could be tested by calculation, and would probably lead to important practical results—viz. the approximate determination of the position of the disturbing body." After quoting the memorandum of July 3, 1841, he proceeds:—"Accordingly, in 1843, I commenced my calculations, and in the course of that year I arrived at a first solution of the problem, which, though incomplete in itself, fully convinced me that the hypothesis which I had formed was quite adequate to account for the observed irregularities, and that the place of the disturbing body might be very approximately determined by a more extended investigation. Having received from the Astronomer Royal, in February 1844, the whole of the Greenwich observations of *Uranus*, I accordingly attacked the problem afresh, and in a much more complete manner than before, and, after obtaining several solutions, differing little from each other, by gradually taking into account more and more terms in the series expressing the perturbations, I communicated my final results to Professor Challis in September 1845, and the same, slightly corrected, to the Astronomer Royal in the following month. The near agreement of the several solutions which I had obtained gave me great confidence in my results, which included a determination of the mass, position, and elements of the orbit of the supposed planet."

that he had been led to undertake this republication by the pressing solicitations of several eminent mathematicians. In introducing the memoir he writes:—"Le problème fut résolu simultanément, en Angleterre par M. Adams, et en France par M. Leverrier, qui, ainsi que le reconnaît M. Adams, a publié le premier les résultats de ses recherches. . . . Il est impossible de rencontrer, dans l'histoire des sciences, une découverte qui fasse plus d'honneur au génie humain. Les lois de Newton recevaient ainsi la plus éclatante des confirmations, et l'Astronomie, désormais indiscutable dans ses principes, était arrivée à l'état de science parfaite. Le Mémoire de M. Adams a valu, à juste titre, à son auteur la plus glorieuse célébrité: il est digne, en effet, de figurer à côté des plus beaux mémoires de Laplace et Lagrange." This republication of the memoir, after an interval of thirty years, in a purely mathematical journal, derives additional interest from the fact that the author himself has added a few notes at the end, some of which relate to the objections made by Professor Benjamin Peirce to the legitimacy of the methods pursued by both Adams and Le Verrier. In Peirce's paper, which was published in 1847, he contended that the period of *Neptune* differed so considerably from that of the hypothetical planets that the modes of procedure adopted were unreliable, so that the finding of the planet was partly due to a happy accident. In reply to this, Adams points out that the objection would be valid if the object in view had been to represent the perturbations of *Uranus* during two or three synodic periods, but that the case is different when, as in this instance, it is only required to represent the perturbations for a fraction of a synodic period.

The honours so freely and deservedly bestowed upon Le Verrier in France and other countries form a striking contrast to the general want of appreciation with which Adams's work was at first received. But there were conspicuous exceptions. In 1847, on the occasion of the Queen's visit to Cambridge, the honour of knighthood was offered to Adams, but this offer he felt obliged to decline. The members of St. John's College, also, were not slow in showing their sense of the honour he had conferred on his college and the University, for in a very short time a fund, producing about 80*l.* per annum, was raised for establishing a prize to be connected with his name. This fund was offered to the University, and accepted on April 7, 1848. The Adams Prize, which is biennial, is awarded for the best essay on some subject of pure mathematics, astronomy, or other branch of natural philosophy. It was awarded in 1857 to Clerk Maxwell for his well-known essay on the stability of *Saturn's* rings.

Before leaving the subject of *Neptune*, it should be stated that Adams always expressed the warmest appreciation of Le Verrier's work. It was a great pleasure to him when they met at Oxford in 1847. In the same year Le Verrier visited Adams at

Cambridge. The honorary degree of LL.D. was conferred upon Le Verrier in 1874 by the University of Cambridge, and it cannot be doubted that this was owing to the action of Adams.

In 1847 he communicated to the Society a paper on an important error in Bouvard's tables of *Saturn*. Having been engaged upon a comparison of the theory of *Saturn* with the Greenwich observations, he was struck with the magnitude of the tabular errors in heliocentric latitude, which could not be attributed to imperfections in the theory. He found that the error was one of computation, two terms of different arguments having been, in effect, united into one.

In 1848 he was occupied with the determination of the constants in Gauss's theory of terrestrial magnetism. This investigation he afterwards resumed, and the calculations connected with it, with which he was occupied in the later years of his life, were left unfinished at the time of death. When failing health prevented him from any longer giving his personal attention to the work, he placed the manuscripts in the hands of his brother, Professor W. G. Adams, for completion.

In 1851 he was elected President of our Society, and held the office for the usual term of two years, during which he delivered the addresses on the presentation of the medal to Peters and to Hind. In 1852 he communicated to the Society new tables of the Moon's parallax, to be substituted for those of Burckhardt. Henderson had compared the parallaxes deduced from observation with those derived by calculation from the tables both of Damoiseau and of Burckhardt, finding a difference of no less than $1''.3$, according as one set of tables or the other was employed. The parallax in Damoiseau's tables is given at once in the form in which it is furnished by theory, but that in Burckhardt's tables is adapted to his peculiar form of the arguments, and requires transformation in order to be compared with the former. When this was done, Adams found that several of the minor equations of parallax deduced from Burckhardt differed completely from their theoretical values as given by Damoiseau. He discovered that these errors were due to Burckhardt's transformations of Laplace's formula, and he succeeded in tracing them to their sources. He also examined carefully the theories of Damoiseau, Plana, and Pontécoulant, with respect to the same subject, and supplied a number of defects and omissions. Burckhardt's value of the parallax having been employed in the *Nautical Almanac*, Adams gave, in addition to the new tables, a table of corrections to be applied to the values in the *Nautical Almanac* for every day of the year from 1840 to 1855 inclusive. This contribution to astronomy is very characteristic of its author. It contains the results of an immense amount of intricate and elaborate mathematical investigation, carried out with great skill and accuracy in all its details, both analytical and numerical, but no part of the work itself is given. The method of procedure is briefly sketched, and the final conclusions are stated in the fewest words and simplest manner possible. No

one unacquainted with the subject would imagine how much difficult and laborious research was represented by these few pages of results. The tables were printed as a supplement to the *Nautical Almanac* for 1856.

As Adams had not taken holy orders, his Fellowship at St. John's College came to an end in 1852, but he continued to reside in the college until February 1853, when he was elected to a Fellowship at Pembroke College, which he retained till his death. In the autumn of 1858 he was appointed Professor of Mathematics in the University of St. Andrews, and shortly afterwards, in the same year, he was elected Lowndean Professor of Astronomy and Geometry at Cambridge, in succession to Peacock. He continued his lectures at St. Andrews, however, until the end of the session in May 1859. In 1861 he succeeded Challis as Director of the Cambridge Observatory.

In 1853 Adams communicated to the Royal Society his celebrated memoir on the secular acceleration of the Moon's mean motion. Halley was the first to detect this acceleration by comparing the Babylonian observations of eclipses with those of Albategnius and of modern times, and Newton referred to his discovery in the second edition of the "Principia." The first numerical determination of the value of the acceleration is due to Dunthorne, who found it to be about 10″ in a century. Tobias Mayer obtained the value 6″·7, which he afterwards increased to 9″. Lalande's value was nearly 10″. The discrepancies were due to the eclipses selected, the results derived from the different eclipses being inconsistent with one another. The history of the theoretical investigations relating to the acceleration may be summed up as follows:—In 1762 the French Academy proposed as the subject of their prize the influence of a resisting medium upon the movements of the planets. The prize was won by Bossut, who showed that the principal effect of such a medium would be an acceleration in their motions, which would be much more sensible in the case of the Moon than in that of the planets. In 1770 the question proposed was whether the theory of gravitation could alone explain the acceleration. Euler obtained the prize, but he was unable to discover any term of a secular character, and concluded that the force of gravitation would not account for this inequality. The subject was proposed again in 1772, Euler and Lagrange sharing the prize between them. The former came to the same conclusion as before, attributing the acceleration to a resisting medium; the latter did not carry the application of his formulæ so far as to complete the investigation. The prize was again offered for the same subject in 1774, the competitors being required to examine whether the fact that the Moon appeared to have a secular acceleration, while there was no sensible effect of this kind in the case of the Earth, could be explained by the theory of gravitation alone, taking into account not only the action of the Sun and the Earth upon the Moon, but also the action of the other

planets, and even the non-spherical figure of the Moon and Earth. The prize was awarded to Lagrange, who, after showing that none of the causes proposed would suffice to explain the secular variation of the Moon, concluded that, *if this variation is real*, it must be produced in some other manner, such as by a resisting medium. But as the existence of such a medium was not confirmed by the motions of the other planets, and was even contradicted by the motion of *Saturn*, which seemed to show a retardation, Lagrange expressed doubts with respect to the reality of the lunar acceleration, resting as it does on observations of eclipses in very remote ages. The next investigation relating to the subject is by Laplace, who showed that the acceleration could be accounted for by supposing that the transmission of the force of gravitation was not instantaneous, but that the rate of propagation was about eight million times that of light. Some years later, however, Laplace unexpectedly discovered the true gravitational cause of the acceleration. While working at the theory of *Jupiter's* satellites, he remarked that the secular variation of the eccentricity of *Jupiter's* orbit produced secular terms in their mean motions. Applying this result to the Moon, he found that the secular variation of the eccentricity of the Earth's orbit produced on the Moon's motion a secular term which agreed very well with the value assigned to it by observation; he found also that the same cause produced secular terms in the motion of the Moon's node and perigee. This result was communicated to the French Academy in November, 1787, and the memoir containing the details of the calculation was published in the following year. The Stockholm Academy of Sciences had already proposed in 1787 the secular variations of the Moon, *Jupiter*, and *Saturn* as the prize subject for 1791, but no essays being sent in, the prize was adjudged to Laplace for his memoir published in 1788.

Laplace's discovery was received with great applause, and the satisfactory explanation of so intractable a variation by means of the Newtonian principles, after so many years of fruitless attempt, was an important event in the history of astronomy. The honour of the discovery might very easily have belonged to Lagrange, for the formulæ given by him in a memoir published in 1783 would at once, if applied to the Moon, have produced Laplace's result. But Lagrange had found that, in the case of *Jupiter* and *Saturn*, these formulæ gave nearly insensible results, so that he did not extend the investigation to the other planets, or to the Moon, although the latter application would only have involved easy numerical substitutions, much simpler than those required for the principal planets.

In 1820, at the instigation of Laplace, the lunar theory was taken in hand afresh by Plana and Damoiseau, the approximations being carried to an immense extent, especially by the former. Damoiseau calculated the acceleration numerically, and found it to be $10''.72$. Plana's process was algebraical,

and he carried the series, of which Laplace had only calculated the first term, as far as quantities of the seventh order. By reducing to numbers the twenty-eight terms of this series he found 10″·58 as the complete value of the acceleration, for which the first term, which alone had been included by Laplace, gave 10″·18. Subsequently Hansen gave the values 11″·93 (1842), 11″·47 (1847), and in his tables published in 1857 the value 12″·18 was used. It does not seem clear, however, to what extent these values are to be regarded as theoretical determinations.*

Thus when Adams published his memoir in the *Phil. Trans.* for 1853 no suspicion had arisen that Laplace's discovery was not absolutely complete, and that the question of the acceleration had not been finally set at rest. In his short paper of only ten pages Adams shows that the condition of variability of the solar eccentricity introduces into the solution of the differential equations a system of additional terms which affect the value of the acceleration. He found that the second term of the series on which the acceleration depends was really equal to $\frac{3771}{64}m^4$, instead of $\frac{2187}{128}m^4$, as found by Plana. The former is more than three times as great as the latter, and the amount of the acceleration is greatly decreased by the correction of the error discovered by Adams. For some time the paper seems to have attracted no attention, but it then became the object of a long and bitter controversy. Plana, who was the person most concerned in the matter, published, in 1856, a memoir in which he admitted that his own theory was wrong upon this point, and he deduced Adams's result from his own equations. But shortly afterwards he retracted his admission, and, rejecting some of the new terms which he had obtained, arrived at a result which differed both from his original value and from Adams's. The question was in this state when Delaunay, by employing his own special method of treating the Lunar Theory and extending the investigation only to the fourth order, had the satisfaction of obtaining Adams's coefficient $\frac{3771}{64}$, a result which he brought before the French Academy in January, 1859. This caused Adams to communicate to the Academy, in the same month, the values which

* Hansen stated in 1866 (*Monthly Notices*, xxvi. p. 187) that he had never disputed the correctness of Adams's theory, but that he was not satisfied with "the development of the divisors into series." If this refers to the expansion of the acceleration-coefficient in powers of $m$, it should be noticed that Adams stated (vol. xxi. p. 15) that he had calculated the value of the acceleration by a method that did not require any expansion in powers of $m$, and found the result to be 5″·70. Hansen says that Adams's theory appeared too late to permit of his using it; "and it was well that it so happened, for I had already found by my own theory a coefficient which represents ancient eclipses as well as could be desired." It seems impossible to resist the conclusion that in this theory the new terms must have been omitted by Hansen, as they had been by Plana and Damoiseau.

he had obtained some time before for the terms in $m^5$, $m^6$, and $m^7$; and he pointed out at the same time that, when these terms were included, the value of the acceleration was reduced to $5''{\cdot}78$, and, inferring that the remainder of the series would be nearly equal to $0''{\cdot}08$, he concluded that the total value of the acceleration was about $5''{\cdot}70$. Soon afterwards Delaunay carried his approximation as far as terms of the eighth order, and by reducing the forty-two terms in the analytical expression to numbers he obtained the value $6''{\cdot}11$. Delaunay's result, which was communicated to the Academy in April, 1859, confirmed the accuracy of Adams's values of the terms in $m^5$, $m^6$, and $m^7$, and also those of $m^2 e^2$, and $m^2 \gamma^2$, which Adams had communicated to him privately. A month after the publication of this paper Pontécoulant made a vigorous attack on the new terms introduced by Adams, which he said had been rightly ignored by Laplace, Damoiseau, Plana, and himself, as they had no real existence. He also objected that if the result of Adams were admitted, it would "call in question what was regarded as settled, and would throw doubt on the merit of one of the most beautiful discoveries of the illustrious author of the 'Mécanique Céleste.'" Shortly afterwards he communicated a paper to the *Monthly Notices* on "the new terms introduced by Mr. Adams into the expression for the coefficient of the secular equation of the Moon," in which he characterised the mathematical process by which these terms had been obtained as 'une véritable supercherie analytique.'" It would appear that Le Verrier did not accept Adams's value, for in presenting a note by Hansen to the Academy in 1860 he states that Hansen's tables afford an irrefragable proof of the accuracy of the value $12''$ which is there attributed to the acceleration. Referring then to the fact that according to Delaunay the secular acceleration should be reduced to $6''$, he proceeds: "Pour un astronome, la première condition est que ses théories satisfassent aux observations. Or la théorie de M. Hansen les représente toutes, et l'on prouve à M. Delaunay qu'avec ses formules on ne saurait y parvenir. Nous conservons donc des doutes et plus que des doutes sur les formules de M. Delaunay. Très certainement la vérité est du côté de M. Hansen."

In the *Monthly Notices* for April, 1860, Adams replied to his objectors, pointing out simply and clearly the errors into which they had fallen. He mentions that before publishing his memoir of 1853 he had obtained his result by two different methods, and that he had subsequently confirmed and extended it by a third. In a series of letters addressed to Lubbock in June, 1860, Plana began by objecting to Adams's value of the term in $m^4$, but he soon admitted its accuracy. Lubbock also was led to apply his own formulæ to the question, and he too arrived at Adams's result. Another calculation was made by Cayley, who, by an entirely different method, also obtained the same result. As Pontécoulant still continued his reiterated attacks upon the accuracy of the new

terms, Cayley's calculation was printed *in extenso* in the *Monthly Notices*, where it occupies fifty-six pages. Delaunay had also made another calculation, in which, by following the method indicated by Poisson in 1833, he was led to the same value. The coefficient of $m^4$ had also been verified in 1861 by Donkin, who used Delaunay's method of the variation of the elements. Thus Adams's value of the term in $m^4$ was obtained by himself in three ways, by Delaunay in two ways, and by Lubbock, Plana, Donkin, and Cayley. Pontécoulant continued his attacks with no abatement of violence in the *Comptes Rendus*. Ultimately he abandoned Plana's value and obtained one of his own, which differed both from Adams's and Plana's.

The whole controversy forms a very extraordinary episode in the history of physical astronomy; the indifference with which the memoir of 1853 was at first received, in spite of the interest and importance of the subject, being followed by the violent controversy which resulted in so many independent investigations by which Adams's result was confirmed. It is not known why Laplace did not carry the calculation beyond the term in $m^2$; but it may be supposed that he regarded the subsequent terms as not likely to modify the value of the first term to any considerable extent. Damoiseau's and Plana's theories passed under the review of Laplace, and may be regarded as having received his sanction. Thus Adams's result not only unsettled a matter which after years of difficulty and struggling had apparently received its full and final explanation, but it detracted from the completeness of a discovery which had long been regarded as one of the greatest triumphs of Laplace's genius. Although the point in dispute was one entirely relating to the mathematical solution of differential equations, in which observation in no way entered, there can be no doubt that the fact that Plana's result agreed with observation, while Adams's did not, created in the minds of many a presumption against the accuracy of the latter. This view was certainly taken by Le Verrier in the passage quoted above, and it seems also to have influenced Hansen. It is curious that it should have been possible for so much difference of opinion to exist upon a matter relating only to pure mathematics, and with which all the combatants were fully qualified to deal, as is clearly shown by their previous publications. The whole controversy illustrates the peculiar nature of the lunar problem, and of the analysis by means of which the results are reached. The complete solution being unattainable by any of the methods which have as yet been applied, the skill of the mathematician is shown in selecting from a vast number of terms those which will produce a sensible influence in that particular portion of the complete solution which is under consideration.

A most admirable account of the whole discussion was given by Delaunay in the Additions to the *Conn. des Temps* for 1864, in which the place occupied by Adams's memoir in the history

of gravitational astronomy is so well summed up that it may be permissible to quote the passage in its entirety :—

" L'apparition du mémoire de M. Adams a été un véritable événement : c'était toute une révolution qu'il opérait dans cette partie de l'astronomie théorique. Aussi le résultat qu'il renfermait fut-il vivement attaqué ; on ne voulait pas l'admettre, et on ne manquait pas de raisons à donner pour cela. Il est, disait-on, en désaccord complet avec les observations ; il ne tend à rien moins qu'à enlever à Laplace l'honneur d'une de ses plus belles découvertes; il est basé d'ailleurs sur une analyse fautive et erronée. Mais parmi toutes ces raisons il n'y en avait pas une bonne ; et la persistance avec laquelle elles ont été présentées et soutenues a produit un effet diamétralement opposé à celui qu'on en attendait : les confirmations de ce résultat tant contesté se sont accumulées à un tel point, qu'il serait difficile de trouver dans les sciences une vérité mieux établie que ne l'est maintenant celle que M. Adams a mise en avant le premier dans son mémoire de 1853. Toutes les objections qui avaient été formulées sont tombées d'elles-mêmes. L'analyse déclarée *fautive et erronée* a été reconnue exacte. L'accord ou le désaccord du résultat théorique avec les indications fournies par les observations n'a plus été regardé comme un moyen de contrôler l'exactitude de ce résultat théorique. Si le désaccord annoncé existe bien réellement, on en conclut simplement que la cause assignée par Laplace à l'accélération séculaire du moyen mouvement de la Lune ne produit pas seule la totalité du phénomène et on ne trouve dans ce désaccord rien qui soit de nature à amoindrir la découverte de l'illustre géomètre français."

These sentences derive additional interest from the fact that they were written by one who was himself the author of the most comprehensive and elegant method by which the lunar problem has ever been treated, and who was the first to recognise the accuracy of Adams's result. In 1866 the Gold Medal of the Society was awarded to Adams for his contributions to the development of the Lunar Theory, the address on the occasion being delivered by De la Rue. In the preparation of this very able address, which contains an excellent history of the problem of the secular acceleration, De la Rue had the invaluable assistance of Delaunay. To complete the account of Adams's connection with the secular acceleration, it should be stated that in 1880, thirty-seven years after Adams's memoir, Airy communicated to the Society a paper on the theoretical value of the acceleration (*Monthly Notices*, vol. xl. p. 368), in which he obtained the value $10''\cdot1477$. At the next meeting of the Society Adams pointed out that in Airy's method of treatment certain terms were omitted, the effect being that the expression for the coefficient was reduced to its first term, so that the result necessarily agreed with Laplace's. Subsequently, taking into account these terms, Airy obtained the value $5''\cdot4773$. Adams took the occasion of the matter being thus

raised again to communicate to the Society the investigation of the acceleration which he had been in the habit of giving in his lectures.

In the *Monthly Notices* for April 1867 he published an account of the results he had obtained with respect to the orbit of the November meteors. Professor H. A. Newton had concluded that these meteors belong to a system of small bodies describing an elliptic orbit about the Sun, and extending in the form of a stream along an arc of that orbit, which is of such a length that the whole stream occupies about one-tenth or one-fifteenth of the periodic time in passing any particular point. He showed that the periodic time of this group must be either 180·0 days, 185·4 days, 354·6 days, 376·6 days, or 33·25 years, and that the node of the orbit must have a mean motion of $52''{\cdot}4$ with respect to the fixed stars. Soon after the remarkable display of the November meteors in 1866 Adams undertook the examination of this question. From the position of the radiant-point observed by himself he calculated the elements of the orbit of the meteors, starting with the supposition that the periodic time was 354·6 days, the value which Professor Newton considered to be the most probable one. The orbit which corresponds to this period is very nearly circular, and he found that the action of *Venus* would produce an annual increase of about $5''$ in the longitude of the node, that of *Jupiter* about $6''$, and that of the Earth about $10''$. Thus the three planets, which alone could sensibly affect the motion of the node would produce about $12'$ in 33·25 years. The observed motion of the node is about $29'$ in 33·25 years, which is therefore inconsistent with a periodic time of the meteors about the Sun of 354·6 days. If the periodic time were supposed to be about 377 days, the calculated motion of the node would differ very little from that in the case already considered, while if the periodic time were a little greater or a little less than half a year, the calculated motion of the node would be still smaller. Hence, of the five possible periods indicated by Professor Newton, four were incompatible with the observed motion of the node, and it only remained to examine whether the fifth period of 33·25 years would give a motion in accordance with observation. In order to determine the secular motion of the node in this orbit the method given by Gauss in his memoir "Determinatio Attractionis &c." was employed. By dividing the orbit of the meteors into a number of small portions, and summing up the changes corresponding to these portions, the total secular changes of the elements produced in a complete period of the meteors was determined, the result being that during a period of 33·25 years, the longitude of the node is increased by $20'$ by the action of *Jupiter*, nearly $7'$ by the action of *Saturn*, and about $1'$ by that of *Uranus*. The other planets were found to produce scarcely any sensible effects, so that the entire calculated increase of the longitude of the node is about $28'$, according very closely with the observed amount of

39′, and leaving no doubt as to the correctness of the period of 23·25 years. In order to obtain a sufficient degree of approximation it was requisite to break up the orbit of the meteors into a considerable number of portions, for each of which the attractions of the elliptic rings corresponding to the several disturbing planets had to be determined. These calculations were therefore of necessity very long, although a modification of Gauss's formula was devised which greatly facilitated its application to the actual problem. Subsequently certain parts of the orbit of the meteors were subdivided into still smaller portions, with the view of obtaining a closer approximation. Unfortunately the mathematical investigations which Adams carried out on this subject have not been published. They exist among his papers, together with a very great amount of numerical work connected with the calculations, and seem to be in a fairly complete state. It is hoped, therefore, that there will not be much difficulty in preparing them for press.

In 1877 Mr. G. W. Hill published a memoir on the motion of the Moon's perigee, in which he calculated that part of $c$ which depends only upon $m$ to fifteen places of decimals by a new method in which the expansion in powers of $m$ was avoided, the numerical value of $c$ being obtained by means of an infinite determinant. The publication of this memoir led Adams to communicate to the Society in November 1877 a brief notice of his own work in the same field, in which, after congratulating Mr. Hill upon his investigation, he mentions that his own researches had followed in some respects a parallel course. In particular he remarks that the differential equation for $z$, the Moon's coordinate perpendicular to the ecliptic, presents itself naturally in the same form as that to which Mr. Hill had so skilfully reduced his differential equations. In solving this equation, which was therefore of Mr. Hill's standard form, he fell upon the same infinite determinant as that considered by Mr. Hill, and developed it in a similar manner in a series of powers and products of small quantities, the coefficient of each such term being given in a finite form. This development was continued as far as the terms of the fourth order in 1868; and in 1875, when he resumed the subject, the approximation was extended to terms of the twelfth order, which is the same degree of accuracy as that to which Mr. Hill had carried his researches. On making the reductions requisite to render the two results comparable, he found that they were in agreement with the exception of one of the terms of the twelfth order, and that this discrepancy was due to a simple error of transcription. He states that the calculations by which he had found the value of the determinant were very different in detail from those required by Mr. Hill's method, but that he had not had time to copy them out from his old papers and put them in order. In this communication, therefore, he confined himself to making known the result which he had obtained for the motion of the Moon's node. After giving an

outline of the method pursued, including the equation derived from the infinite determinant, he arrives at the formulæ by means of which the value of $g$, as dependent only upon $m$, was obtained to fifteen places of decimals.

It is difficult to appreciate too highly the mathematical ability shown by Adams and Hill in devising methods which did not require expansion in powers of $m$, and which yielded with such wonderful accuracy these values of $g$ and $c$. Apart, however, from the mathematical and astronomical interest of the researches themselves, the coincidence of methods and ideas is very striking. But for the publication of Hill's memoir it is probable that no account of these results of Adams's would have been published in his lifetime, and it is not unlikely that he would never have put into writing his views on the mathematical treatment of the lunar problem which give additional interest to this short paper. As far back as 1853, in his memoir upon the secular acceleration, he mentioned that the new terms in the expression of the Moon's coordinates occurred to him some time before, when he was engaged in thinking over a new method of treating the lunar theory, and it is well known that the theory itself, or problems connected with it, constantly occupied his attention. In this paper of 1877 he states that he had long been convinced that the most advantageous mode of treatment is by first determining with all possible accuracy the inequalities which are independent of $e$, $e'$, and $\gamma$, and then in succession finding the inequalities which are of one dimension, two dimensions, and so on with respect to these quantities. Thus, the coefficient of any inequality in the Moon's coordinates would be represented by a series arranged in powers and products of $e$, $e'$, and $\gamma$; and each term in this series would involve a numerical coefficient which is a function of $m$ alone, and which admits of calculation for any given value of $m$ without the necessity of developing it in powers of $m$. This method is particularly advantageous when the results are to be compared with those of an analytical lunar theory such as Delaunay's, in which the eccentricities and the inclination are left indeterminate, since each numerical coefficient admits of a separate comparison with its analytical development in powers of $m$. He mentions also that, many years before, he had obtained the values of the inequalities independent of the eccentricities and inclination to a great degree of approximation, the coefficients of the longitude expressed in circular measure, and those of the reciprocal of the radius vector, or of the logarithm of the radius vector, being found to ten or eleven places of decimals.

We thus see that Adams preferred to treat the lunar theory as far as possible by means of its special problems; and this was also the method which he followed in his Cambridge lectures. Mr. R. A. Sampson, Fellow of St. John's College, Cambridge, who has been making a careful examination of Adams's manuscripts, states that he believes that the investigations he has left will

suffice to form what will practically be a treatise on the lunar theory intermediate to the existing text-books and such complete theories as those of Plana and Delaunay. The manuscripts already put in order by Mr. Sampson contain the development of the infinite determinant and the other researches referred to in this paper.

The *Monthly Notices* for June, 1878, contains a short paper by Adams on a property of the analytical expression for the constant term in the reciprocal of the Moon's radius vector. Plana had found that the coefficients of $e^2$ and $\gamma^2$ in this term vanished when account was taken of terms involving $m^2$ and $m^3$, and Pontécoulant, who carried the development further, had found that this destruction of the terms in the coefficients still continued when the terms involving $m^4$ and $m^5$ were included. Thinking it probable that these cases in which the coefficient had been observed to vanish were merely particular cases of some more general property, Adams was led to consider the subject from a new point of view, and, so far back as 1859, he succeeded in proving that not only did these coefficients necessarily vanish identically, but that the same held good also for coefficients which were much more general, so that the coefficients of $e^2e'^2$, $e^2e'^4$, &c. $\gamma^2e'^2$, $\gamma^2e'^4$, &c. were also identically equal to zero. Further reflection on the subject led him in 1868 to obtain a simpler and more elegant proof of the property in question. He also found subsequently, in 1877, some remarkable relations connecting the coefficients of $e^4$, $e^2\gamma^2$, and $\gamma^4$. Adams himself remarks that the theorem "is remarkable for a degree of simplicity and generality of which the lunar theory affords very few examples." We thus see that a striking result—and one moreover which admitted of being isolated from the rest of the lunar theory—was obtained in 1859, but was not published till nearly twenty years afterwards, although in the meantime he had obtained another and more satisfactory proof. This illustrates the disinclination that Adams seems always to have felt to prepare his work for publication; a disinclination which was mainly due to his desire to obtain a still higher degree of simplification or perfection. The discovery of the additional relations in 1877 shows that his attention was at that time still occupied with the theorem of 1859.

Space does not permit of any more extended account being given of Adams's published astronomical writings, and it would be of little use to mention titles unaccompanied by some description of the contents of the papers. The shorter papers deserve much more detailed notice than might at first sight seem necessary, not only because they frequently consist wholly of results derived from laborious researches, but also because they afford glimpses of the nature and extent of the work with which he was occupied. For forty-five years his mind was constantly directed to mathematical research, relating principally to astronomy; and it is evident that what he had accomplished is very

inadequately represented by what has been published. It is also noticeable that so few of his papers should have appeared quite spontaneously: it frequently happened that he was incited to give an account of something which he had done himself—probably years before—by the publication of a paper in which the same ground was partially covered by some other investigator; in other cases he was called upon to correct some misapprehension which was leading others astray.

As already stated, there can be no doubt that he constantly allowed himself to postpone the immediate publication of his researches, with the intention of effecting improvements in the processes and mode of representing the subject, or of attaining to an even more accurate result. A striking instance of this innate craving for perfection is afforded, even as early as 1845, by his calculation of the second orbit of the new planet. No able mathematician who is engaged upon a fruitful research can continually defer publication with impunity: the subject opens before him; his views expand; the earlier results, so interesting at the moment of discovery, lose their charm in comparison with the problems still unsolved and the novel vistas of thought opened out by them; and the rearrangement and rewriting of the old work—always an irksome task—become intolerable when later and still unfinished developments on the same subject are exciting the mind. In Adams's case the difficulty of satisfying himself, and reaching his own standard of completeness, also contributed to his apparent reluctance to publish investigations to which he was known to have devoted much time, and which were anxiously awaited; such, for example, as his work upon *Jupiter's* satellites. Those who knew him will remember his words when pressed, "I have still some finishing touches to put to it." It does not appear that he ever made any serious attempt to put his longer investigations in order for press, though it is known that occasionally, as his manuscripts on the different subjects increased in bulk, the feeling would come over him that it was time for him to do so. Although there is no similarity between the simple and easy style of Adams's writings and the cold severity of Gauss's, there is a certain resemblance in their mode of work. Each had the same dislike to early or incomplete publication, and "Pauca sed matura" might have been the motto of both. In beginning a new research, Adams rarely put pen to paper until he had carefully thought out the subject, and when he proceeded to write out the investigation he developed it rapidly and without interruption. His accuracy and power of mind enabled him to map out the course of the work beforehand in his head, and his mathematical instinct, combined with perfect familiarity with astronomical ideas and methods, guided him with perfect safety through the intricacies and dangers of the analytical treatment.*

* This method of working characterised him from the first, for in his Tripos Examination it was noticed that "in the problem papers, when every-

He scarcely ever destroyed anything he wrote, or performed rough calculations; and the manuscripts which he has left are written so carefully and clearly that it is difficult to believe that they are not finished work that has been copied out fairly. The sheets are generally dated, and during many years he kept a diary of the work he had done each day, which will be of the greatest use in the arrangement of his papers for publication.

His contributions to pure mathematics show the same power and excellence, and, as the subject affords greater opportunities for the display of elegance and style, they indicate even more plainly the attention he bestowed upon the form of his results, as well as upon the substance. A paper communicated to the Royal Society in 1878 may be specially noticed, in which an expression is given for the product of two Legendrian coefficients, and for the integral of the product of three. The extent of his mathematical interests is perhaps best seen by looking over the series of papers which he set in the Smith Prize Examination. These questions, which cover a wide field of mathematics, clearly indicate the bent of his mind and his favourite subjects of study: they are also noticeable for a high degree of finish, which is very uncommon in examination questions.

Like Euler and Gauss, he took very great pleasure in the numerical calculation of exact mathematical constants. We owe to him the calculation of thirty-one Bernoullian numbers, in addition to the first thirty-one which were previously known. The first fifteen are due to Euler, the next sixteen were calculated by Rothe, the whole thirty-one being given in vol. xx. of Crelle's Journal. Making use of Staudt's very curious theorem with respect to the fractional part of a Bernoullian number, Adams calculated all the numbers from $B_{31}$ to $B_{62}$. The results were communicated to the British Association at the Plymouth meeting in 1877, and were also published in vol. lxxxv. of Crelle's Journal. A much fuller account of the work, which was very considerable in amount, appeared in an appendix to vol. xxii. of the "Cambridge Observations," where the process of calculation of the first, $B_{32}$, and of the last, $B_{62}$, is given in detail. Adams proved that if $n$ be a prime number other than 2 or 3, then the numerator of the $n$th Bernoullian number is divisible by $n$. This afforded a good test of the accuracy of the work.

Having thus at his command the values of sixty-two Bernoullian numbers, he was tempted to apply them to the calculation of Euler's constant. For this purpose, not only the Bernoullian

one was writing hard, Adams spent the first hour in looking over the questions, scarcely putting pen to paper the while. After that he wrote out rapidly the problems he had already solved 'in his head.'" It may be here mentioned that in this examination he received more than double the marks of the Second Wrangler. This affords striking evidence of Adams's mental powers, for he was not a rapid writer.

numbers, but also the values of certain logarithms and sums of reciprocals were required. He accordingly calculated the values of the logarithms of 2, 3, 5, and 7 to 263 (afterwards extended to 273) decimal places, and by their means obtained the value of Euler's constant to 263 places. He also calculated the value of the modulus of the common logarithms to 273 places. The papers containing these results appeared in the "Proceedings" of the Royal Society for 1878 and 1887. Anyone who has had experience of calculations extending to a great many decimal places is aware of the difficulty of manipulating with absolute accuracy the long lines of figures; but this was an enjoyment to Adams, and the work, as carried out with consummate care and neatness, in his beautiful figures, is an interesting memorial of the patience and skill that he devoted to any work upon which he was engaged.

Some may think that the portion of his own time occupied by these calculations might have been more advantageously spent; but there is a charm of its own in carrying still further the determination of the historic constants of mathematics, which has exercised its attraction over the greatest minds. Those who feel the least possible interest in calculation for its own sake, and even dislike ordinary arithmetical computations, have been unable to resist the fascination of doing their share towards the calculation of the absolute numerical magnitudes which are so intimately connected with the foundations of the sciences dealing with abstract quantity. There is a special pleasure also in applying the resources of modern mathematics to obtain the values of the incommensurable constants to such an incredible degree of accuracy, and in verifying the distant figures by methods depending upon subtile principles and complicated symbolic processes of the absolute truth of which we thus obtain so striking an assurance.

Adams had the greatest possible admiration for Newton, and perhaps no one has ever devoted more careful and critical attention to his mathematical works, especially the "Principia." When Lord Portsmouth presented to the University, in 1872, the large mass of scientific papers which Newton left at his death, the arrangement and cataloguing of the mathematical portion of the collection were willingly undertaken by Adams. It was a difficult and laborious task, extending over years, but one which intensely interested him, and upon which he spared no pains. He found that these papers threw light upon the remarkable extent to which Newton had carried the lunar theory, the method by which he had obtained his table of refractions (showing that the formula known as Bradley's was really due to Newton), and the manner in which he had determined the form of the solid of least resistance. In several instances he succeeded in tracing the methods that Newton must have used in order to obtain the numerical results which occurred in the papers. The solution of the enigmas presented by these numbers written on stray

papers, without any clue to the source from which they were derived, was the kind of work in which all Adams's skill, patience, and industry found full scope, and his enthusiasm for Newton was so great that he had no thought of time when so employed. His mind bore naturally a great resemblance to Newton's in many marked respects, and he was so penetrated with Newton's style of thought that he was peculiarly fitted to be his interpreter. Only a few intimate friends were aware of the immense amount of time he devoted to these manuscripts or the pleasure he derived from them. In 1887, on the occasion of the bicentenary of the publication of the "Principia," he was asked by Trinity College to deliver a commemorative address. Unfortunately the state of his health prevented him from undertaking a task which he alone could have adequately performed; but, with the kindness which all who sought his help invariably received, he most freely placed all the stores of his knowledge at the disposal of the present writer, who was appointed in his stead.

He was frequently asked to undertake calculations in connection with eclipses or other astronomical phenomena, and he never hesitated to lay aside his own work in order to comply with such requests. Mr. Downing has written: "His readiness to help, and his magnificent ability to help, will long be remembered at the Nautical Almanac Office," and similar words might be used with reference to the invaluable assistance which he so generously gave in other quarters. Many generations of officers of our Society can testify to his constant willingness to serve the Society, both as a referee and as a contributor to the annual reports. These reports and notices often cost him much time and thought.

He was President of the Society for the second time in 1874–76, when the medal was awarded to D'Arrest and to Le Verrier. In 1870, as Vice-President, he delivered the address on the presentation of the medal to Delaunay, of whose general method of treating the lunar theory he had the greatest possible admiration. In 1881 he was offered the position of Astronomer Royal, which he declined. In 1884 he was one of the delegates for Great Britain to the International Prime Meridian Conference at Washington. This visit to America afforded him great enjoyment and gratification.

He received the honorary degree of D.C.L. from Oxford, of LL.D. from Dublin and Edinburgh, and of Doctor in Science from Bologna and from his own university. He was a correspondent of the French Academy, of the Academy of Sciences of St. Petersburg, and of numerous other societies.

As Lowndean Professor he lectured during one term in each year, generally on the lunar theory, but sometimes on the theory of *Jupiter's* satellites, or the figure of the Earth. During his tenure of the directorship of the Cambridge Observatory in 1870 a fine transit circle by Simms was added to its equip-

ment. This instrument has been employed in observing one of the zones of the "Astronomische Gesellschaft" programme. The zone assigned to the Observatory was that lying between 25° and 30° of north declination.

In 1863 he married Eliza, daughter of Haliday Bruce, Esq., of Dublin, who survives him.

The publication of his complete works has been undertaken by the Cambridge University Press. The first volume, which will be edited by his brother, Professor W. G. Adams, will contain the papers which have been already published, as well as the magnetic work. A memoir of Adams will also appear in this volume. The second volume will contain the lectures and such of the unpublished work as can be prepared for press.

Adams was a man of learning as well as a man of science, and his thoughts and interests were far from being restricted to astronomy and mathematics. He was an omnivorous reader, and, his memory being exact and retentive, there were few subjects upon which he was not possessed of accurate information. Botany, geology, history, and divinity, all had their share of his eager attention. He derived great enjoyment also from novels, and when engaged in severe mental work always had one on hand. Among his more marked tastes may be mentioned his love of early printed books. His collection, containing about eight hundred volumes, eighty of which belong to the fifteenth century, was bequeathed by him to the University Library at Cambridge. The works relate principally to mathematics or astronomy, theology, medicine, and the occult sciences; but he seems always to have bought any fine old book that took his fancy. He was so little given to talk about himself or his pursuits that probably but few of his friends were aware of his passion for black-letter books.

No one who knew him superficially, or who only judged by his quiet manner, could have imagined how deeply he was affected by great political questions or passing events. In times of public excitement (such as during the Franco-German War) his interest was so intense that he could scarcely work or sleep. His love of nature in all its forms was a source of never-failing delight to him, and he was never happier than when wandering over the cliffs and moors of his native county. Strangers who first met him were invariably struck by his simple and unaffected manner. He was a delightful companion, always cheerful and genial, showing in society but few traces of his really shy and retiring disposition. His nature was sympathetic and generous, and in few men have the moral and intellectual qualities been more perfectly balanced. An attempt to sketch his character cannot be more fitly closed than in the words of Dr. Donald McAlister, who knew him well, and attended him in his last illness:—

"His earnest devotion to duty, his simplicity, his perfect selflessness, were to all who know his life at Cambridge a perpetual

lesson, more eloquent than speech. From the time of his first great discovery scientific honours were showered upon him, but they left him as they found him—modest, gentle, and sincere. Controversies raged for a time around his name, national and scientific rivalries were stirred up concerning his work and its reception, but he took no part in them, and would generously have yielded to others' claims more than his greatest contemporaries would allow to be just. With a single mind for pure knowledge he pursued his studies, here bringing a whole chaos into cosmic order, there vindicating the supremacy of a natural law beyond the imagined limits of its operation; now tracing and abolishing errors that had crept into the calculations of the acknowledged masters of his craft, and now giving time and strength to resolving the self-made difficulties of a mere beginner, and all the time with so little thought of winning recognition or applause that much of his most perfect work remained for long, or still remains, unpublished."

He was suddenly attacked by severe illness at the end of October 1889, but he recovered sufficiently to resume his mathematical work in the usual way for several months. In June of the following year he was again attacked by an illness from which he never completely recovered, and he passed away on the early morning of January 21, 1892, after being confined to his bed for ten weeks. The funeral service took place in Pembroke College Chapel, and he was interred in St. Giles's Cemetery, on the Huntingdon Road. There were many who thought that his resting-place should have been in Westminster Abbey, and a royal wish was expressed to this effect; but it is perhaps more fitting that he should lie in this quiet graveyard close to the Observatory where he passed so many happy and peaceful years.

On February 20 a public meeting was held at St. John's College, Cambridge, with the view of taking steps to place a bust or other memorial of him in Westminster Abbey. The proceedings on this representative occasion bore eloquent testimony to the admiration and affection in which he was held by his friends, and to the widespread wish throughout the country for such a memorial to one who was not only a great but a good man. No suitable site for a bust could be found in the Abbey, but a medallion will be placed in an excellent position close to the grave of Newton. This medallion is being executed by Mr. Bruce Joy, who is also engaged upon a bust for presentation to St. John's College. It may be added that five years ago an excellent portrait was painted by Herkomer, which is now in the Combination Room of Pembroke College. J. W. L. G.

Charles Orchard Dayman was born 1803 July 9. In 1820 he went as a pensioner to St. John's College, Cambridge, of which he became a scholar, and in 1824 took his B.A. degree as third Senior Optime. He won in 1826, but did not accept, a

Platt Fellowship at his college, and was called to the Bar in 1829. He was a revising barrister for the South Devon boroughs and afterwards for South Wilts, and in 1856 was appointed a magistrate of the metropolitan police courts, which office he resigned in 1871. Having purchased an excellent refractor by Cooke of York of 5 inches aperture, and Smyth's "Celestial Cycle," he amused himself with a study of the heavens, and in or about 1858 he prepared for Mr. Stanford a new edition of the smaller celestial maps of the Society for the Diffusion of Useful Knowledge containing all the objects in the Cycle. His telescope became the property of his friend, the late Francis Barrow, F.R.A.S. He was one of the nineteen members of the old Spitalfields Mathematical Society who were elected Fellows of this Society on 1845 June 13, "without payment of the usual admission fees and annual contributions (or compositions in lieu thereof), the Mathematical Society having announced its resolution to transfer its valuable library, with its records and memorials, to the Royal Astronomical Society" (*Monthly Notices*, vol. vi. p. 25). Of the nineteen, one only now survives, two having died within the past year. Mr. Dayman did not contribute any papers to the Society. He died on 1892 January 22, in his 89th year. [The above, down to the words "Francis Barrow, F.R.A.S.," is literally transcribed from a sheet of note-paper in Mr. Dayman's handwriting, found among his papers after death. Mr. Dayman wrote the notice of his friend Mr. Chabot, also one of the Spitalfields Mathematical Society, printed in *Monthly Notices*, vol. xxix. p. 123; and this sheet of note-paper was probably written for the *Monthly Notices* in the event of his own death.]

Robert Grant was born at Grantown-on-Spey, N.B., on 1814 June 17. His father, Mr. Robert Grant, was a much respected tradesman of that town. He received the elements of education at the endowed school, which was established by the Earl of Seafield, proprietor of the district, and which provided for instruction in the ordinary branches of education, including the elements of Greek and Latin, in order that the youth of the district should receive the preparatory course of instruction requisite for entering any of the Scottish universities. In this school young Grant exhibited early indications of being an intelligent youth, with more than usual precocity. At the age of nine he commenced the study of Latin, and soon made rapid progress in this and other subjects. But while enjoying the prospect of a promising boyhood, his studies were, at the age of thirteen, interrupted by a serious and long-continued illness, which for six of the most important years of his youth incapacitated him for all school-work. During this long period, when most young men are actively preparing for their future position in life, young Grant was helplessly confined to a bed of lingering sickness, and dependent solely on the affectionate care of his

relatives. After completing his nineteenth year, his health became comparatively restored, when he resolved to renew his former studies, becoming his own instructor. With no other assistance than what he could obtain from books, the young student devoted himself most assiduously to the study of Greek, Latin, French, Italian, and elementary mathematics, with an enthusiasm which the long blank in his career served only to increase. Astronomy was not forgotten, and Sir John Herschel's *Treatise on Astronomy* was a favourite book of study. His astronomical tastes at this time were much encouraged by the interest he took in the return of Halley's comet in 1835, and in the annular eclipse of the Sun, 1836 May 15, when young Grant was able to make his first astronomical observation. In this manner he gradually qualified himself for the high position he afterwards occupied as the honoured historian of the progress of physical astronomy.

When his health became permanently established, Mr. Grant entered upon a short course of study at King's College, Aberdeen, but, considering that there would be a better opening for his special talents in London, he resolved to avail himself of the advantages which a residence in the great metropolis would afford. Here, during the next four years, he obtained employment in the counting-house of an elder brother as a bookkeeper. But in his leisure hours he became a devoted reader of standard works on astronomy and mathematics. It was about this time that he first conceived the notion of writing a brief history of physical astronomy from the earliest ages to the middle of the nineteenth century. He had already accumulated a mass of material suitable for his purpose, but he resolved to defer the commencement of this work until he had had an opportunity of consulting the works on astronomy contained in the great public libraries of Paris. In 1845 he took up his residence in Paris, where he remained nearly two years, supporting himself by giving lessons in English. During the greater part of this time he had a great advantage in the use of the library of The Institute, a privilege he owed through an introduction by one of his pupils. He usually attended the courses of astronomical lectures delivered by Arago at the Observatory, and by Le Verrier at the Sorbonne, including the inaugural discourse of the latter on his appointment as one of the professors.

During the five years following his return to London, in 1847, Mr. Grant devoted most of his time to the preparation of his classic work, *History of Physical Astronomy*. Though still unknown to the leading astronomers, he had already made himself master of the details of most of the principal astronomical investigations, and through a happy personal introduction by Mr. Woodfall, the well-known printer, to Captain R. H. Manners, R.N., then one of the honorary secretaries, he was able to continue his researches by a frequent use of the library of this Society, a concession he has, more than once, gratefully acknow-

ledged. Fortunately, shortly after Mr. Grant's return from Paris, he was introduced to Mr. Robert Baldwin, who, at that time, was the enterprising publisher of an excellent series of works known under the title of "The Library of Useful Knowledge," which received much popular attention. Mr. Grant proposed to contribute to this series a concise history of the principal investigations and discoveries in astronomy which have helped to build up our present knowledge of the physical movements and aspects of the heavenly bodies; or, in his own words, "to exhibit a view of the labours of successive enquirers in establishing a knowledge of the mechanical principles which regulate the movements of the celestial bodies, and in explaining the various phenomena relative to their physical constitution which observation with the telescope has disclosed." The proposal was at once accepted by Mr. Baldwin, and the work was first published in separate parts, or numbers; but, after the issue of the ninth number, this form of publication was discontinued. The first part appeared in 1848 September. The complete work was not published until 1852 March, before which Mr. Grant had been elected a Fellow of this Society. Some of the early numbers of the work were submitted to Professor De Morgan and a few other astronomers, all of whom were at once struck with the accurate and comprehensive grasp of the various theoretical researches, especially by an author hitherto unknown, and it was easily perceived that all the original authorities were carefully consulted by him, and that an attentive consideration was given to each subject. Some of the personal disadvantages under which Mr. Grant laboured are very truly described in the following paragraph taken from the Annual Report of the Council, 1853 February :—

"During the past year Mr. Grant has completed his *History of Physical Astronomy*, a work the first numbers of which formed his introduction to the Society. It is very seldom that the Council are called upon to notice any work of so peculiar a merit. If Mr. Grant had possessed perpetual access to extensive libraries, and peculiar inducements to consult them; if he had passed many years in historical research, had matured his judgment by long habits of discussion with others of like pursuits, and had learned by small attempts how to venture on larger efforts, the production of a sustained history, of extent and matter such as he has published, would have excited admiration, and would have called forth some remark on the true secret of success in such undertakings. But when it is considered that the author had no more connection with libraries than anyone may command for the asking, and no peculiar calling to tempt him into research; that he has not reached middle life, and that his opportunities were furnished, as is understood, by the leisure of ill-health or convalescence; that he had, before the publication of his work, little or no sustained opportunity of communication with those who could have helped to direct his reading or form his judgment,

and that he never published anything whatever previously to the appearance of this well-conceived, well-executed, and greatly-wanted history, the Council, while they state that the work has taken a place among standard books of history from its first appearance, under circumstances which greatly enhance the merit of its author, congratulate the Society upon the prospect of numbering Mr. Grant among its executive members."

After a careful perusal of this remarkable history of the labours of astronomers from the remotest times, the reader cannot fail to be struck with its completeness, and with the rare skill and power displayed in the discernment of the salient points of some of the most difficult researches in astronomy, many of which, from their nature, are of a controversial as well as of an abstruse character. But, in most cases, the author has most scrupulously endeavoured to assign to each of the great men who had been working independently on the same line of research their proper share in the common labour. The President, the late Manuel J. Johnson, Radcliffe Observer, on presenting the Gold Medal of the Society to Mr. Grant, in 1856, very truly remarked, that "nowhere is this more conspicuous than in the discussion relative to the discovery of the planet *Neptune*. By a simple narration of facts he has placed the history of that great event in so clear and so true a light that I believe I am not wrong in saying he has gained an author's highest praise under such circumstances—the approval of both the eminent persons concerned."

In 1852 November Mr. Grant was requested by the Council to undertake the duty of editing the *Monthly Notices*, in succession to the Rev. R. Sheepshanks. His literary tastes encouraged him to introduce some new features in that publication, especially brief notices and abstracts of valuable astronomical papers that had recently appeared in the *Comptes Rendus*, *Astronomische Nachrichten*, and other scientific serials, including the *Memoirs* of different societies at home and abroad. These editorial notices were much appreciated at the time by the Fellows of the Society, and they were continued by him in successive volumes as additional records of astronomical research carried on outside the Society. Mr. Grant continued in charge of the *Monthly Notices* and *Memoirs* of the Society until his appointment by the Home Secretary, in 1859 November, to the important office of Professor of Astronomy and Director of the Observatory in the University of Glasgow, in the vacancy caused by the death of Professor J. P. Nichol. He, however, did not obtain the definite control of the Observatory until 1860 May. He was succeeded by Professor Cayley in the editorship of the Society's publications.

Professor Grant has communicated several interesting papers to the Society. One of these, published in 1853, contains an investigation of the correction to be applied to the apparent ellipticity of a planet, in consequence of the elevation of the Earth

above the plane of the planet's equator. In this important paper Professor Grant has clearly shown that his astronomical talents were not confined solely to the literature of astronomy. Of his other communications to the Society, we need only allude to a paper read at the 1871 December meeting, "On Telescopic Observations of the Phenomena seen in contiguity with the Moon's Limb during Eclipses of the Sun, and the Results which have been therefrom deduced." The principal object of this paper was to point out that the conclusions expressed by Professor Grant on p. 400 of his *History of Physical Astronomy*, relating to the origin and nature of the red sierra observed on the Moon's limb during total eclipses of the Sun, were actually derived from an inductive inquiry based upon a discussion of the observations of all former eclipses recorded in history. The portion of the *History of Physical Astronomy* containing Professor Grant's conclusions on the subject were published in the winter of 1850–51. At this time it was still an open question whether the corona and red prominences were solar or lunar phenomena. It is interesting therefore to note how decided Grant was in the opinion he had given in his book. "While engaged in this enquiry," he remarks, "I endeavoured to show that the phenomena observed during solar eclipses, whether corona, streaks or patches of light, or prominences great or small, are all solar phenomena. While the results of observation were either positively in favour of the solar aspect of the case, or adverse to the lunar aspect, there did not appear to exist a shadow of a proof in support of the lunar origin of the phenomenon." It was a great satisfaction to Professor Grant that, having been a member of the *Himalaya* eclipse expedition to Spain in 1860, he had had the opportunity of witnessing at Toloño the scarlet sierra of which he had given so plausible an interpretation ten years before.

On taking up his residence at the Glasgow Observatory in 1860, Professor Grant found that the only instruments at his disposal were a transit-circle by Ertel & Sons, of Munich, of six French inches aperture, a Dollond refractor of three inches aperture, a sidereal clock, and a few other instruments of minor importance. To these were added, in 1863, the Ochtertyre equatoreal by Cooke, of nine inches aperture, formerly belonging to Sir W. Keith Murray, and a small transit instrument of three inches aperture, the latter chiefly for educational purposes. The funds for the purchase of these instruments, and for the erection of the building in which the equatoreal is mounted, were obtained through the liberality of a few gentlemen, chiefly residents of Glasgow. The equatoreal was frequently employed by Professor Grant in the usual extra-meridian observations of comets, minor planets, and in measures of a selection of double stars, taken from Struve's *Mensuræ Micrometricæ*; but in later years the absorbing demands of the new star catalogue necessitated its use only for the observation of occasional phenomena.

In 1861 Professor Grant proposed to the Town Council of

Glasgow a scheme for controlling certain of the public clocks in the City and Port by a direct current of electricity from the Observatory, so that they might be regulated continuously to exhibit true Greenwich mean time. After some controversy on the subject, the Town Council decided to accept the proposal of Professor Grant, who at once adopted the plan of controlling invented by Mr. R. L. Jones, of Chester, which had been previously employed with success at Liverpool and other places. This system of control of the public clocks has been continued to the present time as a part of the daily duties of the Observatory.

In 1865 May Professor Grant, in co-operation with the Astronomer Royal, made a special series of observations for the determination of the difference of longitude between the observatories of Glasgow and Greenwich by an interchange of galvanic signals of star-transits on four simultaneous clear nights. The details of the observations are inserted in the *Monthly Notices* for 1865 December. Among his other miscellaneous work, Professor Grant favourably observed the great meteoric shower of *Leonids* on 1866 November 13, a large number of which supplied him abundant materials for establishing the position of the radiant point. He has contributed to the *Monthly Notices* the details of this great display, as well as of those observed on 1868 November 13, 1872 November 27, and 1885 November 27. He was also fortunate to observe, at the Glasgow Observatory, the ingress of the planet *Venus* during the transit of 1882.

Some reference should be made here to Professor Grant's valuable contribution to an important correspondence on the celebrated "Chasles" forgeries of the Pascal papers, which assisted more than any other in deciding the true character of these documents. Professor Grant, in the *Times* of 1867 September 20, admirably exposed, in the most conclusive manner, that the whole series of papers submitted to M. Chasles were, on the face of them, utterly fallacious. His argument was based upon certain numerical results contained in the so-called Pascal papers, and he shows clearly that these forgeries were concocted from corresponding numbers in the third edition of the *Principia*, published in 1726, Pascal having died in 1662.

One of the principal objects Professor Grant had in view from the beginning was the observation with the transit-circle of a selected list of stars, in order that their observed positions might be ultimately incorporated into a Glasgow Catalogue of Stars. It was his intention at first to confine the selection to the B.A. Catalogue, but he finally resolved to include in the list several thousands of telescopic stars, mostly taken from the first volume of Weisse's Bessel. The results of his more than twenty years' work with the transit-circle are contained in the "Catalogue of 6,415 Stars for the epoch 1870, deduced from observations made at the Glasgow University Observatory during the years 1860 to 1881." This excellent work, which was pub-

lished in 1883, is not only found useful in supplying sensibly accurate mean places of a large number of stars of the eighth and ninth magnitudes, suitable for employment as reference stars in connection with observations of minor planets and comets, but the places are sufficiently reliable for the determination of proper motions. In the introduction to this volume Professor Grant has determined the proper motions of 99 stars, which, with few exceptions, had previously escaped detection. The preparation of a work of such magnitude must necessarily involve an immense amount of observation and calculation in a well-equipped observatory, but when it is considered that this important catalogue is the outcome of an observatory provided with only a scanty allowance for one assistant, it is difficult to form an adequate conception of the heavy responsibility which must have fallen on Professor Grant during the progress of the calculations and the arrangement of the work for the press.

A Second Glasgow Catalogue of 2,156 stars, in the preparation of which Professor Grant took a great interest, was published a few weeks only after his death. This catalogue contains the mean places of all the stars observed between 1886 and 1892, with the object of explaining certain inconsistencies in the former catalogue, or where there was any suspicion of proper motion shown by a comparison which Professor Grant instituted between the places of the W. B. stars in the First Catalogue, and the corresponding places of Bessel and Lalande. In the introduction he gives the details of 192 new determinations of proper motion. He personally revised the greater portion of this work while passing through the press; but his health must have been failing fast when he wrote in the early autumn that his assistant, Mr. Connell, "was especially helpful to me in the final stage of the catalogue passing through the press, when, in consequence of severe illness by which I was overtaken at the time, the aid of an assistant familiar with the whole details of the work was indispensable." Though still an invalid, Professor Grant had the gratification of completing the introduction, and he continued to examine and correct all the proof-sheets of the catalogue, even down to the last sheet, which he looked over on the morning of his death.

In 1868 the Glasgow Observatory was chosen as one of the stations at which systematic meteorological observations were made in connection with the Meteorological Office in London. Professor Grant was greatly interested in these observations, and faithfully performed all that was required. In 1883 some of the stations, including Glasgow, were closed, but through his strenuous exertions he prevailed upon the Town Council and the Clyde Trust to provide the pecuniary assistance necessary to continue the observations as before.

Professor Grant's intimate knowledge of the French language did good service in the translation of Arago's well-known *Astronomie Populaire*, which was edited by him and Admiral

W. H. Smyth, and published, with editorial foot-notes, in 1858. He also assisted in the translation of Arago's corresponding volume of biographies of eminent scientific men. About this time he had the permission of the Astronomer Royal to attach himself to the Royal Observatory, where he obtained some practical experience in making astronomical observations. This course of instruction extended over nearly twelve months, and the practice he obtained in the use of the instruments was found to be of considerable service to him in after years in his own observatory.

In addition to his astronomical papers printed in the *Monthly Notices*, Professor Grant was an occasional contributor to the *Astronomische Nachrichten*, the *Comptes Rendus*, the *Proceedings of the Philosophical Society of Glasgow*, Charles Knight's *English Cyclopædia*, and other works. He has also delivered courses of astronomical lectures on several occasions, the most important of which were those delivered in 1854 and 1855 at the London Institution, Finsbury Circus, and in 1868, 1869, and 1870 at the Royal Institution. Shortly after, he delivered three similar courses of lectures to ladies at the University of Glasgow.

The honorary degree of M.A. was conferred on Professor Grant in 1855 by the University of Aberdeen, and that of LL.D. in 1865. On 1865 June 1 he was elected a Fellow of the Royal Society. During three years he filled the office of President of the Philosophical Society of Glasgow. As before stated, the Gold Medal of the Royal Astronomical Society was awarded to him on 1856 February 8 for his *History of Physical Astronomy*.

On 1874 September 3 Professor Grant married Elizabeth Emma, daughter of the late A. C. Davison, of Newcastle, New South Wales, and co. Monaghan, Ireland, by whom he leaves one son and three daughters. Although he was the subject of so much physical weakness during his youth, he always appeared to his friends to be in the full enjoyment of health and vigour. He called on the writer at Blackheath in 1892 March, when all who saw him were surprised at the activity of mind and body exhibited by him on that occasion. His brightness was particularly marked when references were made to some pleasant reminiscences of mutual association with some valued astronomical friends long since passed away. For some time, however, it had been observed by his family that his health was visibly failing, and particularly so in the early summer months. He never really rallied again, though his strength was sufficient to allow him to take a continued interest in his work, and to examine and correct the proofs of his Second Catalogue, which was passing through the press during his last illness. For a period of three months preceding his deccase he was seen to become gradually weaker, but his voice was as strong, and his mind as clear, to the last hour of his life as they ever had been. His friends hoped that a brief relaxation from his observatory work in the bracing air of his native Strathspey would restore

him for a time, but he had not been there long before his bodily weakness increased, and during the last few weeks he very gradually and peacefully faded away. The end came rather suddenly. He died at Grantown, on 1892 October 24, in the seventy-ninth year of his age.

Professor Grant was elected a Fellow of the Royal Astronomical Society on 1850 June 14, and was a member of the Council from 1853 to 1860. E. D.

John Hartnup was born at Somerset House, in the apartments of the Society, in 1841, when his father held the position of Assistant Secretary. In 1843 his father removed to Liverpool, having been appointed Astronomer to the Mersey Docks and Harbour Board, and the whole of Mr. Hartnup's life may be said to have been passed upon the banks of the Mersey. He was educated at the Royal Institution School, Liverpool, and at a private academy at Chester, and his scientific training seems to have been effected under his father's sole and careful supervision. He became assistant in the Liverpool Observatory, in 1863, shortly before the Observatory was removed from the Waterloo Dock to its present position at Bidston, and there he gave unremitting attention to those many experiments on chronometrical rates with which his father's name has been so long connected, and which have proved of such signal service to the mercantile marine.

When his father retired from the service of the Mersey Docks and Harbour Board, Mr. Hartnup succeeded him as director of the Observatory, and so remained until his death. His most valuable contributions to science have been his papers on chronometrical management, and his reputation must rest on these. He gave effective support and assistance to the Liverpool Astronomical Society, holding for some time the position of vice-president, and other scientific societies in Liverpool found in him a warm and cordial supporter. He was elected a Fellow of the Royal Astronomical Society on 1886 February 12.

On 1892 April 21 he was killed by falling from the roof of the Observatory, where he had mounted to make some meteorological observations. W. E. P.

Thomas Archer Hirst was born at Heckmondwike (Yorkshire) on 1830 April 22, and was educated at the West Riding Proprietary School, Halifax. The acquaintance he there made with John Tyndall had a great influence on his future life. Tyndall went to Marburg University in 1847, and a visit paid to him there was sufficient to determine Hirst to migrate to that University, to study mathematics, physics, and chemistry. He graduated in 1852, presenting a dissertation on "Conjugate Diameters of the Ellipsoid." From Marburg he went to Göttingen, where he made the acquaintance of Gauss and worked at magnetism under Weber; and thence to Berlin. He was

recalled to England to succeed Tyndall at the Queenwood College, Hampshire, and remained there for three years; and in 1854 he married Anna, youngest daughter of Samuel Martin, Esq., of Loughorne, County Down, Ireland; but the delicate health of his wife necessitated a visit to the South of France during the winter of 1856-7, which was unfortunately unavailing, for Mrs. Hirst died on the return journey in Paris. Dr. Hirst then spent two years abroad, attending the lectures of eminent mathematicians (Chasles, Liouville, Lamé, Bertrand), and writing several memoirs. Early in 1860 he unexpectedly found employment in University College School, of which he was made head master on the death of Mr. Cook. It was during his five years' tenure of this appointment that he made experiments on teaching geometry apart from "Euclid"; and he was one of the founders (in 1871) of the Association for the Improvement of Geometrical Teaching, and its president for the first seven years. In 1865 Dr. Hirst was appointed Professor of Mathematical Physics in University College, London, and in 1867 Professor of Mathematics, in succession to De Morgan. In 1870 he accepted the newly-created appointment of Assistant Registrar in the University of London, in consequence of which he resigned not only his professorship, but his general secretaryship of the British Association, which he had held for four years. Early in 1873, when the Royal Naval College was founded at Greenwich, Dr. Hirst was appointed Director of Studies, which position he occupied until 1883, when ill-health compelled him to resign it, and pass much of his time abroad. He died on 1892 February 16.

Dr. Hirst was one of the original members of the London Mathematical Society (1861); was on its council 1864–1883; was treasurer for several years, and president 1872–1874. He was elected a Fellow of the Royal Astronomical Society in 1866, but never contributed any papers to the Society. He was elected Fellow of the Royal Society in 1861, was three times a member of its council, and twice one of its vice-presidents; and in 1883 he was awarded a Royal Medal. He was also a member of several other learned societies, British and foreign. His scientific work was chiefly confined to pure mathematics, and the excellence of its quality will be gathered from the uniform success which marked his career. Among his more important papers are those "On Equally Attracting Bodies" (*Phil. Trans.* 1857–8); "On Ripples and their Relation to the Velocity of Currents" (*Phil. Mag.*, 1861); "On the Volumes of Pedal Surfaces" (*Phil. Trans.*, 1863); "On the Quadric Inversion of Plane Curves" (*Proc. R.S.*, 1865); and many in the *Proceedings of the Mathematical Society*, 1869–90.

Joseph Kleiber, second son of Henry Kleiber, was born at St. Petersburg on 1863 December 15. He graduated at St. Petersburg University, and while privat-docent delivered lectures on "The Application of Mathematics to Social Phenomena," and

"The Theory of Probabilities." His studies were mainly directed towards astronomy, and he was with Professors Tacchini and Ricco on the river Viatka to observe the total solar eclipse of 1887 August 19. He completed his Russian degree in 1888 by a thesis on "The Method of Smoothing Series of Observations," but his studies having created in him a desire to learn something more of Cambridge mathematics, he came over to England in June 1888, and spent a year in Cambridge. There are many who will long remember this visit of a young Russian enthusiast, attracted from so far by the fame of their university, who worked with the might of a mathematical Hercules. He wrote a sketch of Cambridge life in the *European Messenger* (a Russian review). He returned to St. Petersburg in the autumn of 1889, and was married on October 6. He resumed lecturing at the St. Petersburg University, on the method of least squares and the theory of gravitation; but the symptoms of the fatal disease from which he died had already appeared. He became seriously ill in May 1891, and died from phthisis, at Nice, on 1892 February 12.

In his short scientific life he wrote thirty-two papers, two of which have been published since his death. Eleven of these deal with meteors and shooting stars, the most important being the "Catalogue of 918 Orbits of Meteor Streams from the Observations of Mr. W. F. Denning" (*Monthly Notices*, vol. li. No. 1), and the posthumous paper "On the Displacement of Radiants by the Attraction and Motions of the Earth" (*Monthly Notices*, vol. lii. No. 5). Eleven papers deal with probabilities and statistics in their application to astronomy and meteorology, one or two are on pure mathematics, and one or two on miscellaneous subjects.

He was elected a Fellow of the Society on 1889 December 13.

Thomas Lee was born in the parish of Galston in the year 1818, and first came to Kilmarnock, which he afterwards made his home, as a boy of fourteen, to fill the post of commercial clerk. Four years later he went to London, where he still continued to be engaged in commercial pursuits. After visiting Paris and other cities he returned to Kilmarnock, and took up the profession of tuition, his first school being in Queen Street. When the appointment of mathematical and commercial master in the Kilmarnock Academy became vacant, the success and reputation Lee had already attained as a teacher caused him to be selected from a large number of candidates—a selection which his future career abundantly justified. He by no means confined his instructions to his pupils to their preparation for a business life, a work in which he was very successful, but took a great interest in training many of them in the higher branches of mathematics and astronomy, and secured for them more than a rudimentary knowledge of those sciences. He was greatly assisted in his astronomical teaching by the erection of the observatory in Morton Place, which was provided with two good reflecting telescopes and other astronomical instruments. This

observatory was built by the late Baillie Thomas Morton, whose daughter Mr. Lee married in 1841. He retired from public educational life in 1876, but as session clerk, an office to which he had been appointed in 1872 on the death of his son-in-law, Mr. Smith, and which he held up to the time of his death, he still took part in the public life of the town, and the celebration of his golden wedding-day in 1891 was made an occasion by his fellow-workers in the Kirk Sessions and his many friends for testifying to the regard in which he was held by them. He was a man of great information, clear intellect, keen scientific spirit, and fine personal character, and was widely respected. He was elected a Fellow of this Society 1856 June 13. He died 1892 January 24, leaving a widow, two sons, and four daughters.

William Edwards Michell, of the Fort, Newquay, was the son of the late Mr. William Michell, Registrar of the Court of the Vice-Warden of the Stannaries of Cornwall and Devon. He was born at Truro, 1840 March 14, and was educated at private schools and at Christ Church, Oxford. Inheriting from his father a considerable property at Newquay, on the north coast of Cornwall, Mr. Michell soon became interested in its local affairs, and for many years he was one of the foremost in promoting the various improvements which have transformed this hitherto unknown seaside village into a place of popular resort. For more than thirty years he was an officer in the Royal Cornwall and Devon Miners' Artillery Militia, and during the last ten years its lieutenant-colonel in command. He was also a magistrate for the county of Cornwall, and a member of the County Council. Colonel Michell was interested in the investigations of the probable origin of the local antiquities of Cornwall, and he has contributed papers on "Camps and Tumuli," and other archæological remains to the *Journal of the Royal Institution of Cornwall.* He also took a personal interest in the progress of astronomy, and in the proceedings of this Society, though he had few opportunities for attending the meetings. He had shown symptoms of declining health during the autumn, and in October he left Newquay to obtain the special advice of a London physician. His friends entertained great hopes of his recovery, but he never permanently rallied, and died at Woolwich on 1892 November 5, in the fifty-third year of his age.

Colonel Michell was elected a Fellow of the Society on 1874 June 12.

The Rev. Isaac Vale Mummery was born in 1812 at Canterbury, and died in 1892 October 2. He was educated for the ministry at Coward College, and was successively settled as pastor at Tunbridge, Ratcliffe, and Bethnal Green. A brief account of his work will be found in the *Evangelical Magazine* for 1892 November. He was elected a Fellow at the Annual

General Meeting, 1853 February 11. He did not contribute any papers to the Society, but on 1873 June 13, the "Rev. J. V. Mummery presented to the Society a fine photograph from a painting of the late Mrs. Somerville" (*Monthly Notices*, xxxiii. p. 461). The printer's error, "J. V." for "I. V." in the initials, also occurs in the note of his election.

Ankitam Venkata Nursing Row was born in the year 1827. He comes of an ancient stock settled on the banks of the Krishna. Mr. Nursing Row's father was Diwan to the Nawab of Masulipatam, and his uncle a Dubash of the East India Company at Ganjam. Mr. Nursing Row lost his father when an infant; so he was brought to Vizagapatam, and brought up under the care of his maternal grandfather. His education was entrusted at first to Mr. Porter, and then to the Rev. J. Hay, M.A., D.D., the father of modern education in the Northern Circars. Mr. Nursing Row entered the service of the East India Company when he was young, and early rose to the position of a deputy collector; but his wife inherited a large estate from her mother, and he resigned his connection with the public service for the purpose of managing the estate. He found connected with it a small observatory, provided with a transit instrument, erected by his father-in-law, Mr. G. V. Jugga Row, an ingenious and wealthy Zemindar, who invented a pluviometer. Finding the management of the estate afforded him plenty of leisure, Mr. Nursing Row devoted himself to the study of astronomy. He learnt the rudiments of the science from Dr. Hay, and, in correspondence with eminent English astronomers, who kindly gave him a good deal of help, began to develop the institution left by his father-in-law. He had a new observatory built in 1874, and provided it with a 6-inch equatoreal instrument, a transit circle, and a sidereal clock. He was appointed Honorary Meteorological Reporter to the Government of India for Vizagapatam. The Government evening time-gun at this station having been discontinued on 1871 September 20, Mr. Nursing Row offered to bear the expenses of the firing, which the Government of Madras allowed as a special case, and this useful institution has been maintained ever since. He founded a photographic studio in this town. He was elected Fellow of the Royal Astronomical Society in 1871, and of the Royal Geographical Society in 1872. The dearest wish of his heart was to provide the Observatory with the means for photographing the sky. For this purpose he obtained celestial photographic instruments, but died on 1892 June 18, before he could complete the arrangements.

Benjamin Scott was born in 1814, and was the son of Mr. Benjamin Scott, who at that time was a junior officer of the Corporation of the City of London. Mr. Scott was educated at Totteridge, and, on leaving school, entered the service of the

Corporation at once, becoming nominated for a junior clerkship before his age rendered him eligible for such a post. His steady perseverance and strict attention to the minutiæ of the duties devolving upon him won him the favour of his superiors, and he rose steadily in his position until, on his father's death, he was appointed Chief Clerk to the Chamberlain of the City. On the death of his chief, Mr. Anthony Brown, he came forward as a candidate for the vacant office, but was not successful on that occasion. Later, however, on the death of Sir John Key in 1858, he was elected to the post with absolute unanimity, and he remained Chamberlain to the day of his death; his connection with the Corporation thus extending over a period of sixty-five years, and only being interrupted for a short time during Sir John Key's term of office, when for a while he laid aside all City work to devote himself to benevolent and philanthropic work.

His services to the City as Chamberlain during the long period of more than one-third of a century were of the highest order. His management of the finances of the Corporation was most wise and able, and by a judicious rearrangement of the bonds and loans he saved the Corporation large sums annually, thus enabling many well-considered schemes which must otherwise have been dropped for lack of funds to be carried through. Of these schemes, one of the most important, in which he took the most lively interest, was the acquisition of Epping Forest as an open space for the people of London.

He was a most earnest and skilful defender of the Corporation against the numerous attacks which have been made upon it; and his "Statistical Vindication of the City of London," a work upon which he devoted immense care and pains, remains as a monument of his efforts.

Conscientiousness and thoroughness were amongst his chief characteristics, and however small a matter might be he bestowed upon it the same care and accuracy "as if he were drawing a will or framing an indictment." He literally died in harness, for although he was not seen at the Guildhall again after Christmas, 1891, he was engaged upon his official work almost to the last day of his life. He died in 1892 January 17, only three days after the death of the beloved wife, to whom he had been married for nearly fifty years, and who was buried with him at Weybridge Cemetery, 1892 January 19. He was elected a Fellow of this Society 1860 April 13.

Thomas Taylor was born in London on 1814 January 1, and died from chronic bronchitis at Montreux on 1892 March 6. After education by a private tutor, he entered St. Bartholomew's Hospital, where he took the prize for botany. He was in general practice for some years, and also lectured on Chemistry both at St. Thomas's Hospital and at the Middlesex Hospital. Long and serious illness compelled him to abandon his connexion with the latter institution twenty-five years ago, and from that time he

gave little attention to scientific pursuits. He was the first to make known in England Dr. Schoenbein's process for manufacturing gun-cotton, and was the inventor of what is known as parchment paper. He was elected a Fellow in 1845 June, as a member of the Spitalfields Mathematical Society, but never contributed any paper to this Society.

George Turnbull was born at Luncarty on 1809 September 2. He received his early education at the Perth Grammar School, and finished his studies at Edinburgh University, after which he came to London to study engineering under Telford, one of whose most trusted assistants he became. Mr. Turnbull was in 1829 elected an Associate of the Institution of Civil Engineers, and until Telford's death in 1834 was his professional representative and confidential clerk, and was connected with a large number of important dock, harbour, and other works. Among these may be mentioned the Bute Docks at Cardiff, the Folkestone and Dover Harbour works, the Shakspeare Tunnel, and the Great Northern Railway. In 1850 he was selected for the responsible position of Chief Engineer of the East Indian Railway, an appointment which he held till 1863, when he retired from active professional life, but he was afterwards employed as arbitrator in various disputes connected with Indian railways. He was in India during the Mutiny, and gave many proofs of his energy and courage in the conduct of engineering works in spite of opposition and difficulty.

Mr. Turnbull became a Member of the Institution of Civil Engineers in 1840, and was elected a Fellow of this Society in December of the same year. He was a Member of the Senate of the University of Calcutta, and a Fellow of various other societies. In 1875 he settled at Rose Hill, Abbott's Langley, on a small estate which he had purchased, where he lived in retirement till his death on 1889 February 29.

W. Mattieu Williams was born in London 1820 February 6. His father was Welsh, and his mother Swiss. He was unfortunate in losing his father when quite young, and his mother having married again when he was only eleven years old, he was at that early age obliged to leave school, and thrown entirely on his own resources. He was, however, adopted by a friend of his father, Mr. Z. Watkins, who eventually bequeathed a large fortune to him. Through him he was apprenticed to Mr. Street, optical instrument maker, of London, and for the next nine years he attended, after office hours, the night classes at the Mechanics' Institute, and spent his half-holidays and spare moments in reading. Owing to a great capacity for grasping details and an aptitude for mastering difficulties, he was at the age of nineteen well up in most subjects, but with a decided predilection for the physical sciences. He then, by the help of Mr. Watkins, went through a course of study at the Royal Infirmary at Edinburgh, but he was of too sensitive a disposition to become a good surgeon.

When Mr. Williams came of age he inherited some money from his father, and decided to spend two or three years in travelling, for the purpose of finishing his education. He travelled, always on foot, through France, Switzerland, Italy, Greece, and on to Constantinople. He then returned to Edinburgh, and became acquainted with George Combe, with whose views on education he was in hearty sympathy; and a result of their friendship was the founding of the Williams Secular School, in which experimental science formed an important part of the curriculum.

He went to Birmingham in 1854, and at the foundation of the Birmingham and Midland Institute he was appointed master of the classes then being formed in the industrial department. In 1862 Mr. Williams invented a special retort for distilling paraffin from "cannel" coal, and in 1863 was appointed analytical chemist to Sir John Brown & Co.'s Atlas Iron Works at Sheffield; and it was during this time that he wrote his first book, entitled *The Fuel of the Sun.*

In 1872 Mr. Williams came to Norwood, and gave up his time to writing and lecturing. He gave several lectures at the Royal Institution, and three courses of Cantor Lectures on mathematical instruments, iron and steel, and chemistry of cookery, at the Society of Arts.

Mr. Williams was a large contributor to scientific and educational journals, especially under the headings of "The Chemistry of Cookery," "The Chemistry of Iron and Steel Manufacture," "The Philosophy of Clothing," "Science in Short Chapters," and "Through Norway with a Knapsack." He was elected Fellow of this Society on 1872 June 14, and of the Chemical Society on 1857 May 18. He died on 1892 November 28. S. T. K.

Annibale de Gasparis, foreign Associate of this Society, and formerly Director of the Royal Observatory of Capodimonte, and Professor of Astronomy of the Royal University of Naples, died on 1892 March 21.

Born in Bugnara, in the Province of Aquila, 1819 November 9 (his father being parish doctor of this small village), A. de Gasparis made his first studies at the seminary of Chieti, and there became familiar with the classic writers for whom he ever after manifested a great love and predilection.

In 1838 he came to Naples to study mathematics, of which he had already taught himself the elements. For a time he was a student at the school of engineering, but previous to completing his engineering course he became possessed of a passion for astronomy, and asked and obtained the permission of Capocci to be admitted as a pupil of the Royal Observatory of Capodimonte. He there soon became distinguished for his love of science, and his rare aptitude for observation and diligent calculation. Notwithstanding his exceptional gifts he remained for

eleven years in this humble position, which was much below his capacity.

Towards the end of 1848 he began a review of the smaller stars with the Reichenbach equatoreal, and the help of the Berlin map of the heavens, in order to search for new planets. He was probably encouraged to this work by the recent discoveries of Astræa, Hebe, Iris, Flora, and Metis, which had fallen to the lot of Hencke, Hind and Graham, in a short space of time. On 1849 April 12, he discovered his first planet, Hygeia, and the following year, within an interval of a few months, two others, Parthenope and Egeria. Become famous by these discoveries, he received the gold medal of this Society and the Lalande prize from the Academy of Paris, and was appointed in 1851 Professor of Astronomy of the Royal University of Naples. At the death of Capocci, in 1862, he was appointed director of the Observatory of Capodimonte.

He continued his observations in search of new planets for several years. Besides the three already mentioned, he discovered Irene (four days after Hind), Eunomia, Psyche, Massilia, Themis, Ausonia, and Beatrix. He alternated these astronomical observations with theoretical work, both in astronomy and mathematics, publishing a long series of important memoirs. De Gasparis was of strong physique, and worked hard, interrupting his observations only by brief readings of the classics in which he so much delighted.

About 1885, he began to suffer from creeping paralysis, which gradually became aggravated, and in 1889 the condition of his health was such as to render the fulfilment of his many official duties impossible. He therefore established himself in a country house not far distant from the observatory where he had worked for about forty-five years.

Many honours were bestowed on him; he became a member of the Academy of Italy, as well as of several foreign societies; and he was a senator of the kingdom from 1861.

He was elected a Foreign Associate of this Society 1850 December 13.

Amédée Ernest Barthélemy Mouchez was born in Madrid on 1821 August 24, was educated in Paris and Versailles, and at the age of sixteen entered the Naval School at Brest. He was gazetted midshipman in 1839, lieutenant in 1845, and captain in 1861. The most important event in his naval career was his splendid defence of Havre during the Franco-Prussian War. This side of his life is so little known to those familiar with his career as an astronomer, that a few sentences in relation to it are perhaps not out of place here. "Le capitaine de vaisseau Mouchez fut nommé par le Gouvernement de la Défense nationale, le 18 octobre 1870, commandant des forces de terre et de mer de la place du Havre, ville presque ouverte, que défendaient à peine quelques forts détachés. . . . Il entreprit de

couvrir les approches de la ville par plusieurs lignes de retranchements et par des redoutes, dont il choisit les positions et traça immédiatement les plans, et, grâce à l'énergique impulsion qu'il sut donner aux travaux de défense, les forts, qui constituaient alors les seuls ouvrages de la place, furent au bout de quelques semaines reliés par une ligne fortifiée qu'il arma de pièces de marine . . . L'ennemi avait envahi la Normandie, et la ville de Rouen se sentit menacée; sa municipalité appela aussitôt M. Mouchez et le chargea d'effectuer autour de Rouen des travaux de défense: mais, avant qu'il eût le temps d'exécuter le plan qu'il avait conçu . . ., la ville de Rouen fut occupée par l'armée du général Von Goeben. Les troupes qui couvraient Rouen se retirèrent vers le Havre, . . . et y trouvèrent un abri qui leur permit de se réorganiser. Dès la prise de Rouen l'ennemi tenta une pointe vers le Havre; mais il rebroussa chemin, en apprenant que la ville avait été mise en état de défense; il renouvela cette tentative . . . mais il fut arrêté . . . M. Mouchez perfectionnait les ouvrages de défense . . . et conserva, jusqu'à la signature de la paix, le commandement de la place du Havre et la flotille de la Seine." *

His naval career was also distinguished by some admirable survey work. He spent the five years 1856–1861 in surveying the coasts of Paraguay and Brazil, and a similar period later on the survey of the coast of Algeria; and this work led to his appointment as Member of the Board of Longitudes. In 1874 he organised the expedition to St. Paul to observe the Transit of *Venus*. The climatic conditions of this island of the southern seas made success very problematical, and there were also exceptional dangers in disembarking and otherwise; but the position was so favourable for observation that the risks were undertaken, and, thanks to Mouchez, the enterprise was successful in every way. He gave an account of the expedition before the five Academies in 1875 October, and he was promoted Contre-Amiral and elected Member of the Academy of Sciences.

After the death of Le Verrier, M. Mouchez was appointed (on 1878 June 27) Director of the National Observatory, and he held the post of director till his death in the past year.

From the time of his appointment the staff have displayed the greatest energy, both in carrying on and completing investigations already commenced and in initiating new ones. During his directorate, the arrears in the annual volumes were made up, twenty-one volumes of Annals being published in his fourteen years of office. The re-observation of Lalande's 48,000 stars was immediately pushed forward, and progress has been so rapid that the work of observation is now practically complete, and half of the great catalogue is already printed and distributed, while another quarter is in the press. The catalogue is founded

* *Discours de M. Louis Brindeau, Maire de la Ville du Havre, prononcé aux obsèques de M. Mouchez, le Mardi, 28 Juin* 1892.

on 500,000 observations made at Paris during the last fifty years. Other meridian investigations of a fundamental character have received careful attention from M. Loewy and M. Périgaud. In 1885 the Brothers Henry constructed a photographic object-glass, and commenced a series of experiments in astronomical photography, the success of which is too recent to dwell upon here. M. Loewy was given every assistance in his project for *équatoriaux coudés*, and the work on aberration and refraction on which he proposed to employ one or more of them. Recently a new spectroscopic department, under M. Deslandres, has been established at the observatory. The *Bulletin Astronomique* was founded by M. Mouchez; and a summer observatory was established on the Pic du Midi.

For the last eight years Admiral Mouchez has been of opinion that the Paris Observatory should be transferred to a new site. On 1884 February 4 he presented a memoir to the Academy of Sciences on the necessity for constructing a branch to the observatory. He pointed out that the present site was in a part of the city becoming more and more populous, and proposed to retain there only the museum, an office for calculations, and three or four instruments for instruction; and to construct near Paris an observatory of the first-class, furnished with all the improvements of modern science, the cost of which could be defrayed by selling the ground outside the present observatory. This proposal was negatived by a large majority of the committee appointed to consider it, there being a strong feeling against selling any portion of the present observatory territory. But Admiral Mouchez never gave up the idea. In his subsequent reports he again and again referred to the proposal. He considered that the employment of instruments of great precision or of great optical power were alike impossible at the present observatory owing to the instability of the ground in the one case, and the opacity of the Paris atmosphere in the other. But nothing had yet been done in the direction of moving the observatory at the time of his death.

But it will be as the initiator of the international scheme for charting the heavens that M. Mouchez will be remembered. In presenting the first photograph taken by the Brothers Henry to the French Academy in 1885, Admiral Mouchez remarked on the advantages which a complete photographic survey of the heavens would secure. Dr. Gill had offered to co-operate with the Paris Observatory in such a survey, and it was then estimated that six or eight years would suffice for the work.

In 1887 an international conference was summoned to Paris by Admiral Mouchez, acting under the auspices of the French Academy, and supported by the Government, for consideration of this plan in detail; and a thoroughly representative assembly of nearly sixty astronomers and savants was the result.

The conference resolved generally that recent advances in astronomical photography made it imperative that the astronomers

of our epoch should jointly undertake a photographic survey of the heavens at the present time, taking care to determine the constants which would allow of the positions and magnitudes of stars being determined with the greatest possible precision. Eighteen observatories have provided themselves with instruments essentially of the same pattern, and most of them are now at work on this chart. Details, far more numerous than was at first anticipated, were settled at two other conferences in 1889 and 1891; or by correspondence between members of sub-committees. But it would be difficult to over-estimate the importance of Admiral Mouchez's energy and labour in this preliminary work. His activity in communicating with the sub-committees, his tact and courtesy on occasions of divergence in opinion, his keenness in perception of the wisest course, have smoothed difficulties which, if not perhaps insurmountable, have at times bid fair to delay the undertaking very seriously. With his help a start has been effected which will go far to ensure a successful issue. One of the last things M. Mouchez did as Director, was to establish (in 1892 February) a micrometrical service for measuring the photographs.

Towards the end of his life, Admiral Mouchez suffered from almost total deafness, which was a serious hindrance to some of his work; but the devotion of his friend, Miss Klumpke, did much to obviate the difficulties that might otherwise have arisen. From her many of the particulars in the present brief notice have been gathered. We learn from her that on 1892 June 24, "whether feeling the need of a well-deserved rest, or with some mysterious prevision of his approaching end, the Director convoked MM. Davanne, Loewy, Wolf, Paul and Prosper Henry, and read out the programme he had prepared on various subjects under discussion, requesting them to share with him the responsibility of their solution. Having thus made, as it were, his scientific will, having confided to their hands the great work he had begun, he returned to his beautiful country-seat at Wissons. On arriving there he declined all nourishment and laid down to rest, and before another dawn he had passed peacefully away, surrounded by his loving and devoted family." He died on 1892 June 29.

Lewis Morris Rutherfurd was born at Morrisania, N.Y., on 1816 November 25. He graduated at Williams College, where he gave evidence of considerable scientific ability and zeal. He was called to the Bar in 1837, but having married a lady of some fortune early in his career, in 1849 he abandoned the law to devote all his energies to science. He first came to Europe, and remained there for some time travelling and studying. On his return to New York he erected a small observatory (transit, clock, and equatoreal) at the back of his house, and his observations were from the first of considerable importance. In 1863 he published in *Silliman's Journal* a paper on the spectra of stars, Moon, and planets, which is the first published attempt at classi-

fication of star spectra.* He there suggested a rough classification of the spectra into three groups: "First, those having many lines and resembling the Sun, all reddish or golden stars; secondly, white stars, like *Sirius*; the third group comprising *Spica*, *Rigel*, etc., also white stars, but showing no lines."

In the course of his observations with the spectroscope Mr. Rutherfurd discovered its use for making a photographic object-glass, and in 1864 he succeeded in devising and constructing an $11\frac{1}{4}$-inch glass (*Am. J. of Sc.*, 1865 May) of fifteen feet focal length, corrected for the photographic rays, with which many very successful photographs were taken of the Sun, Moon, and stars. In 1868 he finished a 13-inch—an ordinary achromatic, to which a third flint lens could be attached in a few minutes when it was desired to use the telescope photographically. The beautiful photographs taken with these instruments were in 1890 presented to the Columbia College Observatory, together with twenty folio volumes, of about 200 pages each, containing the measures of many of the plates. A complete catalogue of them, given by Mr. J. K. Rees (*Annals of the N.Y. Acad. of Sc.* vol. vi. 1891 June) shows 175 solar, 435 lunar, and 664 stellar plates, and 174 plates of the solar spectrum. The measures were made by Rutherfurd with micrometers of his own devising. In the first he used a long screw, and that the measures even with this instrument were excellent was shown by Dr. B. A. Gould in two papers read to the Nat. Acad. of Sc. in 1866 and 1870. The merest summary of these papers was published at the time, and the details were not printed till many years after. In 1870 Dr. Gould was, as is well known, called to Cordoba for (as he then thought) three years, and he left the publication of the star measures till his return. He took with him the $11\frac{1}{4}$-inch telescope, but the object-glass was unfortunately cracked in transit. He put together the pieces and made some photographs of the southern stars, but afterwards obtained another lens. It was fifteen years before Dr. Gould returned to the States, and could arrange for the printing of the two memoirs by the National Academy. The real investigator, Mr. Rutherfurd, meanwhile made no effort towards this consummation, partly

* It should not be forgotten that Fraunhofer, using a prism before the object-glass, observed the spectra of *Capella*, *Betelgeux*, *Procyon*, and *Pollux*, in which he recognised the solar D; and also of *Castor* and *Sirius*, which were different. These results in 1823 were really the first to show that the spectra of stars differ from each other and from that of the Sun. Immediately after Kirchhoff's discovery of the true meaning of the Fraunhofer lines, Donati in Florence, Rutherfurd in the United States, and Huggins and Miller in England, all worked independently (and unknown to each other) at the spectra of stars and planets. Donati published a paper on stellar spectra in the *Annali del Museo Fiorentino* for 1862, but his method and results were very imperfect. When Dr. Huggins and Dr. Miller arrived at the Royal Society, on 1863 February 26, to read their first paper (dated 1863 February 17), they were surprised to find the copy of *Silliman's Journal* containing Rutherfurd's paper mentioned in the text.

from ill-health and partly from that dislike to the act of publication only too prevalent among eminent scientific men. But the long-screw micrometer was not satisfactory, and Rutherfurd was led to devise one with a glass scale, the principle of which is now too well known to need description. The measures made with the glass-scale micrometer are at last being reduced and published by the Columbia College, and Mr. H. Jacoby has shown in two memoirs (on the *Pleiades* and the *β Cygni* group) how excellent are photographs and measures alike. Thus the chief part of Rutherfurd's astronomical work is only now being made generally accessible.

During 1870 Mr. Rutherfurd constructed a ruling-engine, described and figured in *Appleton's Cyclopœdia.* With this beautiful apparatus he produced superb interference gratings on glass and on speculum metal. Some of the ruled plates had 17,000 lines to the inch; they were superior to all others down to the time when Professor Rowland perfected his machine.

Among his other work may be specially mentioned his photograph of the solar spectrum by using a bisulphide of carbon prism (1864); his method of adjusting a battery of prisms to minimum deviation (1865); his demonstration of the stability of a collodion film (1872); and his project for using a glass divided circle instead of one of metal (1876).

Mr. Rutherfurd was one of the founders of the National Academy of Sciences. He took a most important part in the International Meridian Conference at Washington in 1885. For more than twenty years he was a member of the Board of Trustees of Columbia College, and received the degree of LL.D. at the Centenary in 1887. Weak health prevented his accepting many scientific engagements in which he was invited to take a prominent position. For twenty years past he was compelled to spend his winters either in Florida or in the south of France. He contracted a severe cold on his journey south in 1891, and never fully recovered from its effects. He died peacefully, and without apparent pain, on 1892 May 30, in his seventy-sixth year.

He was elected an Associate of this Society on 1872 November 8.

## Proceedings of Observatories.

The following reports of the proceedings of observatories during the past year have been received from the directors of the several observatories, who are alone responsible for the same :—

### *Royal Observatory, Greenwich.*

The past year has been an exceptionally heavy one in various ways, and has somewhat severely taxed the energies of the staff. Two new assistants were appointed in February to fill vacancies which had existed for some time; and the observatory was for some months without the services of a clerk. Important changes in the buildings have occupied much of the attention of the Astronomer Royal; and, finally, two important longitude operations have required nearly the whole time of Mr. Hollis during three quarters of the year, and a considerable portion of that of the Chief Assistant.

It might therefore be expected that the regular work would necessarily suffer to some extent; but it is reassuring to find that the arrears (chiefly in the printing) are not serious, and will probably be effaced early in 1893. The total number of transits observed in the year 1892 is 6,212, and of zenith-distances 5,607, which numbers compare favourably with those for any previous year. The total number of stars observed in 1892 was 1,722.

The reductions for the Five-year Catalogue of Fundamental Stars from observations in the years 1887–1891 are completed, and the Catalogue will be published as an appendix to the volume of Greenwich Observations for 1891. Meanwhile the resulting star-places have been communicated to the Superintendent of the *Nautical Almanac* and used by him in the *Nautical Almanac* for 1896 (just published).

The N.P.D.'s of the Ten-year Catalogue have been analysed by comparing the results for the separate years with the mean. The comparison suggested periodic fluctuations of latitude of the kind found by Mr. Chandler in his recent investigations; and on a more direct reduction of the Greenwich observations from 1851 to the present time being undertaken by Mr. Thackeray. Mr. Chandler's doubly periodic variation of the latitude (in about 365 and 427 days respectively) was very satisfactorily confirmed. The results have been given in two papers communicated to the Society by Mr. Thackeray (*Monthly Notices*, liii. pp. 2, 120).

The mean error in R.A. of Hansen's Lunar Tables, with Newcomb's corrections, as deduced from 111 observations with the Transit-Circle in 1892 is + 0$^{s}$·069, agreeing well with the results for previous years since 1883.

Recent observations of horizontal flexure by means of the collimators show that the coefficient is still very small. The apparent correction to nadir observations deduced from reflection observations of stars is − 0″·25, a rather large quantity. No correction for flexure, or for the above nadir discordance, has been applied to the observations apart from the R − D correction.

Observations with the altazimuth were intermitted during the months May to October, owing to the great pressure of other work. In the remaining months the Moon was observed regularly during the first and last quarters. The proposition to replace this instrument by a Universal Transit-Circle, as described by the Astronomer Royal (*Monthly Notices*, lii. p. 480), has been sanctioned by the Admiralty.

Five comets have been observed during 1892 with the Sheepshanks Equatoreal, viz.: Comet (*a*) 1892 (Swift) on fourteen nights; (*c*) 1892 (Winnecke) on one night; (*d*) 1892 (Brooks) on nine nights; (*f*) 1892 (Holmes) on nine nights, and (*g*) 1892 (Brooks) on three nights.

Twenty-five occultations of stars (including seven disappearances and three reappearances of stars during the lunar eclipse of 1892 May 23); the occultation of *Uranus* by the Moon on July 3; the occultation of 73 *Piscium* by *Jupiter* on May 23; and 49 phenomena of *Jupiter's* satellites, have been observed with the Equatoreals, by one or more observers.

With the Astro-photographic Equatoreal 489 plates, involving 1,222 exposures, have been taken during the past year. The total time of exposure, exclusive of trails for orientation, was 127$^{h}$ 8$^{m}$. Of the plates, 88 were Chart and 220 Catalogue plates, 67 were for instrumental adjustment, 75 of *Nova Aurigæ*, 13 of the *Pleiades*, 16 of various regions, and 10 were attempts at Chart plates cut short by clouds. The plates of *Nova Aurigæ* have been measured for determination of the magnitude of this star at different epochs, and the results have been communicated to the Society. Four of the miscellaneous plates were exposed on *Jupiter*, a concave enlarging lens (specially made by Dallmeyer) being used to magnify the image about 15 times. The photograph micrometer used for the measurement of Transit of *Venus* (1874) photographs has been modified for use with the stellar plates. The measures can be made quite independently of the *réseau*, which will be an advantage if this auxiliary has ultimately to be dispensed with, owing to the decomposition of the film, which it seems difficult to prevent. As regards the selection of guiding stars for the plates of the chart:—Since the date of the last report the remainder of the catalogue for zone +60° to +65° (Rome) has been sent to Father Denza; the

second 12 hours of R.A. of the zone $+25°$ to $+29°$ (Oxford) has been sent to Professor Pritchard; the catalogue for $12^h - 18^h$ R.A. for the zone $-3°$ to $-5°$ (San Fernando) has been completed, and the approximate star-places for R.A. $0^h - 12^h$ and R.A. $18^h - 24^h$ have been communicated to Dr. Becker, of Strassburg, who is determining accurate places by meridian observation.

The $12\frac{3}{4}$-inch Merz refractor, dismounted in 1891 November to make room for the new 28-inch refractor, was mounted in place of the Lassell reflector on 1892 April 13, the Thompson photo-heliograph being attached to the tube. In its present position, however, it cannot be effectively used owing to the interference of the new building of the proposed Physical Observatory, on the central tower of which it will, as is hoped, soon be mounted, together with the Lassell dome. The old south-east dome was dismounted in November, and operations for the erection of the new 36-foot dome which is to cover the 28-inch refractor, were commenced by Messrs. T. Cooke & Sons in the middle of December. No spectroscopic observations have been made during the year.

Photographs of the Sun have been taken with the Dallmeyer 4-inch photo-heliograph on 210 days, and of these 518 have been selected for preservation, including 29 photographs with a double image of the Sun, taken to determine the position of the wires with reference to the parallel of declination.

For the first three months of the year the Dallmeyer photo-heliograph was mounted on the first floor of the new museum, from which it was removed on April 6 to its old position in the wooden dome south of the Photographic offices. Here it remained during the summer months until the Sun was no longer sufficiently high to be observed over the roof of the new museum building, and on September 9 the photo-heliograph was once again transferred to the new museum.

Photographs of the Sun have also been taken with the Thompson photo-heliograph on 35 days during the year. A new enlarging lens has lately been supplied for this instrument by Messrs. Ross & Co., with very satisfactory results as regards flatness of field and freedom from distortion. Photographs have also been received from India and Mauritius up to December 6, leaving seven days in the year ending on that day for which no photograph is yet available for measurement.

The increase in the solar activity which was so marked in 1891 has continued during 1892. The Sun has not been free from spots on a single day; as many as ten or eleven distinct groups have often been seen on the disc at the same time. Several of the groups observed have been of very great size and complexity, and one (that of Feb. 5–18) was by far the largest ever photographed at the observatory. It is premature yet to decide whether the actual maximum has been attained, but the great increase in the number of the spots appears to point to its being near at hand.

The operations for determining the longitude of Montreal were successfully concluded in September. In the spring (April and May) two series of observations were completed, the observers at Greenwich and Waterville (Ireland), and at Montreal and Canso (Nova Scotia), being interchanged between the two series, but no exchange of observers being made across the Atlantic. For the autumn operations Professor McLeod, of Montreal, came to England, and Mr. Turner crossed to Canada, and interchanges of observers were made as in the spring, between the pairs of stations separated by the cable.

The following table shows the number of nights of observation at the several stations in the four parts.

| Part. | Greenwich. | | Waterville. | | Canso. | | Montreal. | |
|---|---|---|---|---|---|---|---|---|
| | Full Nights. | Half Nights. | Full Nights. | Half Nights. | Full Nights. | Half Nights. | Full Nights. | Half Nights. |
| I. | 5 | 2 | 3 | 2 | 6 | ... | 3 | 1 |
| II. | 6 | ... | 5 | 2 | 3 | ... | 2 | 3 |
| III. | 8 | 4 | 4 | 3 | 4 | 3 | 6 | 3 |
| IV. | 7 | 3 | 2 | 4 | 10 | 1 | 5 | 1 |

Signals were exchanged on each night between Greenwich and Waterville, between Waterville and Canso (the cable termini), and between Canso and Montreal. A few experimental signals were exchanged between Greenwich and Montreal, being automatically registered and repeated at the intermediate stations, but the results were not so satisfactory as those of the signalling independently in sections. Discussion shows that the transatlantic signals are practically as good as those over short land lines, excepting that the time of transmission is greater, and hence there is a larger chance of error from the necessary assumption of equality in the time of transmission in opposite directions.

The reductions are so far advanced as to show that the determinations in the spring and autumn for Waterville are accordant *inter se*, and agree with the geodetic determination within $2''$, *i.e.* well within the limits of error due to local attraction. The results for the transatlantic stations are also so far satisfactory, judged by the standard of accordance *inter se*.

The longitude of Paris was also redetermined in June and July (in the interval between the two series for Montreal), in concert with the officers of the French Service Géographique. Observations were made at Greenwich on seventeen, and at Paris on twenty nights. The reductions are not yet sufficiently advanced to pronounce definitely on the subject of the discordance found in 1888.

While in England, Commandant Defforges took the opportunity of swinging his pendulums at this observatory, and at Leith Fort, Edinburgh, where Captain Kater had made observations. Thus the French pendulum observations will be connected with the English and Indian.

The building of the south wing of the Physical Observatory was commenced in November last, and this addition will, to some extent, relieve the observatory of the present great pressure on available space; but the relief will not be by any means complete until the whole of the proposed cruciform building is finished.

The electric-light installation has been sanctioned by the Admiralty, and the details of the scheme are practically settled.

The volume of Greenwich observations for 1890 was passed for press in August last, and is being distributed. The volume for 1891, as was remarked earlier in this report, is not so well advanced as usual, but it is hoped soon to make good this deficiency.

In February, Captain Grant, R.E., of the Ordnance Survey, consulted the Astronomer Royal as to the determination of the boundary of Mashonaland, in concert with Portuguese officers. The most difficult part of this operation was the fixing of a meridian of longitude on the spot, and without, of course, any possibility of telegraphic communication. The method of Moon culminations, observed with a small transit, was recommended; and a rough prediction of the Moon's errors was made for Captain Grant's use. A comparison of the prediction with observations since made is given in the *Monthly Notices*, vol. liii. p. 11.

Captain Viniegra, director of the San Fernando Observatory, paid a visit to Greenwich on April 4, and discussed the work of the Astro-photographic Chart.

Sir G. B. Airy, late Astronomer Royal, who died early in the past year, gave another proof of his attachment to the Royal Observatory by bequeathing to it such of his books, manuscripts, &c., as might be considered useful; and Mr. Wilfrid Airy has accordingly transferred to our library 94 volumes, 134 unbound tracts, and the voluminous manuscript calculations of the Numerical Lunar Theory.

### *Royal Observatory, Edinburgh.*

The contract for the buildings of the new Royal Observatory was signed on 1892 May 25, the work being entrusted to Messrs. W. and J. Kirkwood, of this city. The plans were prepared by Mr. W. Wybrow Robertson, of H.M. Office of Works. A short description of them will be useful in following the progress of the work already done.

The main building extends 180 feet from east to west, terminating in two towers surmounted by domes, or rather "drums." The eastern tower, rising to a height of 75 feet, will contain the 15-inch Grubb refractor, while the 24-inch reflector from Calton Hill will be mounted in the western dome, the top of which will be some 44 feet above the ground at that end. A single range of rooms, opening on a corridor on the south, extends from tower

to tower, only the end rooms occupying the whole depth of the building. The roof is designed as an asphalted platform, 113 feet long and 22 feet broad, affording free communication between the towers. Beginning from the west, the apartments are thus arranged: Spectroscope room, general laboratory (with three isolated piers), electrical room, cleaning room, mechanics' workshop, chronograph and class room. Light and dark photographic rooms, as well as a computing room for the equatorial and photographic work, are situated in the eastern dome. Several useful basement rooms adjoining the large tower have been constructed.

A central extension of the main building towards the south, measuring some 80 feet by nearly 24 feet, will contain the chief computing room, the hall, stairs, and ante-room, the director's room, and, lastly, the fireproof library—a lofty apartment 34 feet 6 inches by 23 feet 9 inches, with a light iron gallery affording access to the upper shelves. There is a top storey to the southern part of this portion of the building 66 feet in length, designed for optical work, into which a large beam of light can be reflected from a siderostat on the flat roof to the north. An iron railway down the centre of the room, insulated from the rest of the floor, will support the instruments. It will be seen that this room practically forms a horizontal telescope.

In the basement will be placed the heating apparatus, a dynamo and accumulators for supplying electricity for lighting the observatory and illuminating the instruments. In the observatory there will thus be only one chimney, the draught of which can be controlled when requisite.

The transit circle will be housed in a separate building eighty feet to the west of the western tower, accessible by a covered way. By means of light walls and roof of corrugated iron, shaded by louvres of tinned steel, it is hoped that uniformity of inside and outside temperature may be secured. As an extra precaution against the egress of warmer air immediately over the instrument, the opening in the roof will be at a lower level than the air-outlets in the eastern and western sections of the roof.

The remaining buildings are the astronomer's house, two assistants' houses, arranged as a double villa, and a gate-lodge.

Owing to the steepness of the approach, and partly also to the position of the site in a public park which rendered it undesirable to cut up the roadway, an inclined railway was made from a temporary siding at Blackford Hill Station on the Suburban Railway. At the siding are also the sheds at which the greater part of the stone cutting is done. Hence little dead weight beyond the prepared materials has to be hauled up the hill. The siding and inclined track were finished by the middle of August. Meanwhile the rock excavations for the library and other parts of the buildings had been in progress since July 11, so that the first stone could be laid on the concrete bedding on

October 4. By the end of the year the whole of the main building with its east and west towers was well in progress. The walls are built of grey sandstone, from Hailes Quarry, to the west of Edinburgh, but are faced with a reddish freestone procured from Doddington Hill, in Northumberland.

Including the cost of drainage, water-pipes, pumping-chamber, and fencing, the expenditure at the close of the year was a little over 4,000*l*. Greater progress would have been made but for the severe frosts, which not only stopped all building, but also cut off the supplies of stone from the quarries.

At Calton Hill, Mr. Heath has carried on the time service, the meteorological reductions, and the preparation of weather-returns for the Registrar-General for Scotland, as in previous years. The revision of the Edinburgh star places has also been carried a stage further. A redetermination of the latitude with the mural circle is also in progress.

In July, Lieutenant Gratzl, of the Austrian Navy, observed the times of vibration of a pair of invariable pendulums at Calton Hill, preparatory to a visit to Jan Mayen, where the observations were to be repeated.

Fifteen astronomical circulars have been issued in the course of the year. The thanks of observers are due to Messrs. Berberich, Schorr, H. Oppenheim, and Archenhold, for their important contributions to these circulars. No. 22 is specially interesting, as containing the earliest notice of the outbreak of *Nova Aurigæ*. It is almost superfluous to add that this wonderful object was first seen by Dr. T. D. Anderson, of this city, who also independently picked up Comet Holmes two nights after its discovery in London. The *Nova* was observed on every favourable occasion until its disappearance, not only at Calton Hill, but also at Dunecht, by Dr. L. Becker, who went there the moment the star's extraordinary character was perceived. The results of these observations are published in the *Transactions of the Royal Society of Edinburgh* (vol. xxxvii., p. 51). On its reappearance in the autumn, the star was again studied with the Dunecht refractor by Professor Copeland, with the valuable aid of Mr. J. G. Lohse, who was staying there for a short time. A later attempt made by Dr. Becker to secure a photograph of the spectrum was unsuccessful, owing, probably, to a want of sufficient clear sky for a lengthy exposure, for the same apparatus yielded a spectrum of *Jupiter*, full of minute detail.

In November and December Dr. Becker completely dismounted and packed the transit circle, together with the piers and collimators. The granite-work of these piers and their foundations is very beautiful and solid, and will be used again at Blackford Hill. The task of separating these massive cut stones was much lightened by the aid of the experienced and skilled mason, Mr. John Smith, who had erected them twenty years ago, and who, it is hoped, will rebuild them in their new quarters.

In continuation of his published work on the Low Sun Spectrum, Dr. Becker has reduced the late M. Thollon's Solar Spectrum to Rowland's wave-lengths and compared them with his own results. He has also revised the papers on *Nebulæ* and on *The Latitude of Dunecht*, mentioned in last year's report.

Shortly after the new year, Dr. Becker was appointed successor to the late Dr. Grant in the Chair of Astronomy in Glasgow.

Just before daybreak on the morning of March 8, fire broke out in the official residence of the Astronomer Royal for Scotland. When it was first perceived, one corner of the house was already burning fiercely, from foundation to roof—five stories in all. Happily the inmates escaped unharmed. Notwithstanding the promptest exertions on the part of the police and the fire-brigade, the corner where the fire broke out, the whole of the roof, and the top flat were destroyed by fire, while much injury was inevitably done to the rest of the house by water. Fortunately the library was not materially damaged, though for months the books required continual turning over to prevent the inroads of mildew. The most valuable works entirely escaped injury, owing to their position in well-glazed cases in another part of the house. Practically ten months were required before the house and library were again in order.

By an oversight, wrong figures were given for the latitude of the new observatory on p. 190 of *Monthly Notices*, vol. l. The approximate latitude is 55° 55′ 28″·0.

### *Royal Observatory, Cape of Good Hope.*

The inadequacy of the computing force for the past ten years has led to large and growing arrears of reduction which no effort on the part of the existing staff could overtake. The Lords Commissioners of the Admiralty having granted an addition to the computing staff, it appeared to H.M. Astronomer that the time had arrived to make a supreme effort to overtake these arrears. Accordingly, all meridian-observing not absolutely required has been suspended during the year; the assistants have thus been enabled to give much additional time to the work of reduction, and, as will be afterwards evident, a great amount of the arrears has been overtaken, although not so much as would have been but for the serious illness of two of the assistants.

The series of meridian observations of the Sun, *Mercury*, and *Venus*, with the brighter clock-stars, was continued until September 21, when it was interrupted by necessary repairs to the floor of the Transit Room and Central Hall. On removing the old flooring-boards of the Transit Room, it was found that the framework of beams supporting the floor, and even the strong wooden pillars which supported the roof, rested on the foundation of the transit circle piers. This explained the great difficulty which

had often been experienced in getting sufficiently steady images in reflex and nadir observations. Complete reconstruction of the framework of the floor and support of the roof became necessary—a work that was at once undertaken by, and is still in the hands of, the Director of Works Department.

The observations secured with the transit circle have been :—

| | R.A. | N.P.D. |
|---|---|---|
| Observations of the Sun (both limbs) ... ... ... | 77 | 74 |
| „ Mercury ... ... ... ... ... | 39 | 37 |
| „ Venus ... ... ... ... ... | 48 | 49 |
| „ Azimuth stars ... ... ... ... | 82 | ... |
| „ other stars ... ... ... ... | 789 | 509 |
| | 1035 | 669 |

| | |
|---|---|
| No. of determinations of Collimation ... ... ... | 43 |
| „ „ Level ... ... ... | 247 |
| „ „ Run ... ... ... ... | 2[illegible]0 |
| „ „ Flexure ... ... ... | 35 |
| „ „ Nadir ... ... ... | 280 |

Besides these, meridian observations of the Declination of Mars and the comparison stars of the Washington Programme were obtained on forty-four nights.

The weather, during the year, has been the most unfavourable for observing ever known at the Cape. The rainfall at the observatory was 40·9 inches, as compared with the average (for the past fifty-one years), 25·8 inches ; but this proportion in no way expresses the much greater relative proportion of cloudy weather. Icebergs have been reported within sixty miles of Cape Point, and an unusual number of whales have entered False Bay and Table Bay. These facts probably point to an abnormal northward set of Antarctic currents ; and hence, perhaps, the unusually damp and cloudy weather which has been experienced.

The following occultations of stars by the Moon were observed :—

| | |
|---|---|
| Disappearances at dark limb ... ... ... | 9 |
| Reappearances „ ... ... ... | 4 |
| | 13 |

With the heliometer, observations for the parallax of six stars were made on twenty-four nights ; forty observations of position-angle and distance of stars occulted by the Moon on 1891 November 15 were also made. In accordance with Dr. Lohse's request, forty-five observations of the position-angle of the polar-spot on *Mars* were made near the time of opposition.

The zenith telescope has been employed by Dr. Gill in an

investigation on the Constant of Aberration and Change of Latitude; 574 observations were secured by him.

Comet *a* 1892 (Swift) was observed on fourteen nights.

The damp and cloudy weather has been especially unfavourable for photographic work. Many preliminary experiments had to be made before all practical details connected with the plans of the Astrophotographic Congress could be satisfactorily worked out. Regular work was begun on July 26, and so unfavourable has been the weather that only "catalogue" plates have as yet been attempted. Of these have been obtained :—

| | |
|---|---|
| Successful plates ... ... ... | 307 |
| Rejected ... ... ... ... | 58 |
| Standard areas ... ... ... | 35 |
| Total | 400 = 1200 exposures. |

The following miscellaneous photographs were taken, chiefly previous to July 26, when regular astrophotographic charting commenced :—

| | Plates. | Exposures. |
|---|---|---|
| Adjustments, screen experiments, &c. ... | 50 | 211 |
| Stars occulted by Moon 1891 November 15 | 26 | 52 |
| $\eta$ Argûs ... ... ... ... ... | 13 | 13 ($5^s$ to $12\frac{1}{4}^h$) |
| $\alpha$ Centauri (as a double star) ... ... | 5 | 136 |
| $\omega$ Centauri (cluster) ... ... ... ... | 3 | 3 ($14^m$, $1^h$ $53^m$, $3^h$) |
| $\kappa$ Crucis (cluster) ... ... ... ... | 1 | 1 ($35^m$) |
| Lunar eclipse 1892 May 11 ... ... ... | 10 | 10 |
| Plates for stellar parallax ... ... ... | 16 | 85 |
| Comparison of areas in various galactic latitudes ... ... ... ... | 12 | 15 |
| Total | 136 | 526 |

Much labour has been given to experimental work in measuring plates and reducing the measures, determining *réseau* errors, &c., but it has become necessary to suspend all such work for the present, until other arrears are overtaken.

The state of the reductions of the meridian observations is as follows: The Cape General Catalogue for 1885, the Annual Meridian Volumes for 1885, 1886, and 1887 are ready for press, and the volumes for 1888 and 1889 are being copied for press. The observations made in 1890 are completely reduced and examined to "apparent place," and the "mean places" are computed and partly examined. For 1891 the computation and examination are complete to "apparent place"; the duplicate copy of the corrections to reduce to mean place has to be computed and the corrections applied. For 1892 the R.A. is completely reduced and examined to April 17, and the N.P.D. to the end of the year.

With respect to the extra-meridian observations, the chief labour of reduction has been connected with the discussion of the observations made in 1889 and 1890 in carrying out the proposals of H.M. Astronomer for observing the minor planets *Victoria* and *Sappho*. The preliminary part of this work (the discussion of the heliometer triangulation of the comparison stars) was completed early in the year, and a short outline of the results of the work is published in the *Ast. Nach.*, No. 3107.

The discussion of the observations of *Victoria* is now nearly complete, and will be quite so (so far as the Solar Parallax is concerned) before this report is in the hands of the Society.

The comparison of the observations with the ephemeris has apparently demonstrated with great weight that Le Verrier's value of the constant of the Lunar Equation must be diminished about $\frac{1}{60}$ part, and that, with the resulting value of the Solar Parallax, the accepted value of the Moon's mass must be diminished by more than one per cent. The amount of the correction to the Lunar Equation comes out nearly the same from each of the three lunations over which the observations extend, and from the Declinations as well as the Right Ascensions; although, of course, with much lower weight from the Declinations than the Right Ascensions.* These results depend upon heliometer observations made at the Cape, Yale, Leipzig, Göttingen, and Bamberg, in 1889 (June 10 to August 24, both days inclusive). During the whole of this period there were secured over 800 observations (involving 4 pointings each) in each hemisphere, and there are only six nights during the whole period on which no observations were secured at one or more of the observatories. The combined efforts of many astronomers, and the generous co-operation of the directors of many observatories have made it possible to determine places of the comparison stars so exactly that the absolute path of a planet has (for the first time in the history of astronomy) been followed over nearly three complete lunations, with greater precision at every point than has the annual parallactic ellipse of any fixed star whose parallax has as yet been determined.

For the *Sappho* observations the equations of condition are formed, and the whole work will be ready for press within a few months.

A small volume of observations of comets 1880–1889 (except the great comet of 1882, already published), with more accurate places of the comparison stars and final revision of all the observations, is ready for press.

Tables for facilitating the computation of "star-corrections" to mean place have been completed by Mr. Finlay on the plan which

* The definitive determination of the Lunar Equation requires a rediscussion of the work, based on new heliocentric ephemerides of the Earth and *Victoria*; and in the computation of the former the lunar perturbations, instead of being taken from Le Verrier's tables, should be rigorously computed from the co-ordinates of the Moon.

he proposed in *Monthly Notices*, vol. l., p. 497, from declination 0° to 75° and, on a modified plan, from 70° to 88°. They are being employed in computing the check corrections for 1891, and are found to save much time. If, after further trial, this experience is confirmed, it is proposed to print the tables in the publications of the observatory.

So severe has been the pressure on the still inadequate computing force, that it has been impossible to attempt the reduction of the heliometer stellar parallax observations, the observations of the mutual distances and position-angles of *Jupiter's* satellites, the zenith telescope observations, the measures of *réseaux*, a large collection of measures of photographic plates, the reduction of occultations, as well as a valuable series of meridian observations of the Sun, Moon, and fundamental stars, made under Sir Thomas Maclear's directorate in the years 1861–1870, which should certainly be published.

Professor Kapteyn reported, under date 1892 June 12, that the last plate of the Southern Photographic *Durchmusterung* had been measured; and he now informs me that the first sheets of the Catalogue will be ready for press in February. An apparatus, designed by H.M. Astronomer, for engraving the maps of the *Durchmusterung* has been received from Messrs. Troughton and Simms.

The field work of the geodetic survey was completed on September 30, and Major Morris and his party are now engaged at the observatory in completing the reductions. The whole of the observed angles are completely corrected for run and level, and the definitive lengths of the three base-lines (Natal, Port Elizabeth, and Kimberley) have been deduced. A preliminary computation of the whole triangulation has been made, and a mean fundamental origin in latitude, longitude, and azimuth determined. The small corrections to the angles have also been computed, which are necessary to equalise the length of any of the four base-lines * (computed from any other base through the triangulation in any direction), with its measured length. The final portion of the computations is now in progress, viz., the computation of the small final corrections so necessary to complete the harmony of the gridiron chains of triangles at their points of junction.

Major Morris rejoins his corps on completion of this work, after ten years' service in South Africa, rendered conspicuous by the energy, tact, and ability which he has devoted to the work of the survey, and the success with which he has overcome the many difficulties which beset such a work in a country where the scarcity of water and difficulties of transport and supply are so great.

* The fourth base-line is that measured by Maclear (in Zwartland), the observed and computed lengths of which have been found to agree very harmoniously with the modern work.

### *Cambridge Observatory.*

During the year the work has progressed on the same lines as in recent years.

The reductions of the observations are nearly completed up to the end of this year, and the arduous task of reduction to epoch for the zone stars, and arrangement of each individual result in order of right ascension, has been accomplished for nearly the first twenty hours, embracing about 33,000 places of small stars. The smaller catalogue, which will give the place of each star from the mean of all the observations, has made some progress, but cannot be taken up vigorously until the larger be completed.

The work with the transit circle has been chiefly directed to the observation of stars which had been overlooked in the preparation of the observing catalogues, or had been imperfectly observed, and to the observation of stars which had been compared with comets.

Several requests for accurate places of stars contained in the zone assigned to this observatory have been promptly met.

The Northumberland Equatoreal has been got into much better working order. The woodwork of the roof was much decayed, and has been replaced by sound material; so that the dome now revolves freely; the driving clock was put into the hands of a competent workman, and now carries the instrument round with comparative regularity. Under these improved conditions the telescope has been used much more frequently than during previous years. Preparation was made for observing the eclipse of the Moon on May 11, but clouds prevented observation.

The weather was very unfavourable in November—we only got five nights with Holmes' Comet. In these we obtained thirty-three comparisons with adjacent stars, using the square-bar micrometer. The places of some of the stars have been observed with the transit circle.

### *The Newall Telescope, Cambridge Observatory.*

The Newall telescope (25 inches aperture) has been used for observation on 122 nights in the course of the year 1892.

Some difficulty was experienced in the final adjustment of the instrument, and this was traced to the obliquity of the line of collimation to the declination axis. Alterations have been made, which have so far reduced the error that further trouble has not arisen.

The new clockwork and gearing, constructed by Sir Howard Grubb, has just reached Cambridge (1893 January 2); and only the old inefficient clockwork has been available hitherto, so that observations involving the use of clockwork have been made at great disadvantage.

Under these circumstances some time has been devoted to the observation of the following planets :—*Saturn*, *Jupiter*, *Mars*, *Venus*, *Uranus*, *Neptune*, and drawings have been made on several occasions.

Attempts have been made several times to see Barnard's satellite of *Jupiter*. Twice a faint object was suspected near the place indicated in Marth's ephemeris, but never with such certainty as to warrant a statement that the satellite had been seen.

[Note on February 10. The satellite has since been seen with certainty twice.]

A drawing (date, April 29) of Comet *a* 1892 (Swift) shows rifts in the tail, such as the photographs of Russell, Barnard, and Wolf record. It may be remarked that the drawing was made some time before receipt of the photographic results.

The work of the year has necessarily been mainly of a preparatory nature, which, with the exception of two branches need not be specified.

Some preliminary visual photometer work has been attempted. The variation in brightness of *Nova Aurigæ* has been followed, both in the earlier and in the later appearance. A wedge photometer, having a wedge interval of about 1 inch per magnitude, is being calibrated, with a view to its application to the photometry of faint stars ; it is found that the wedge is incapable of extinguishing a 10th magnitude star at its thickest end and a 15th magnitude star at its thinnest end, when the full aperture of the objective is used. Some of the regions chosen by the American committee on standards of stellar magnitude have been investigated, and this work is being continued.

Through the kindness of Mr. Lockyer two objective prisms of $10\frac{1}{2}$-inch aperture and $7\frac{1}{2}$ degrees angle were put at our disposal by the Science and Art Department, South Kensington. These were mounted with a rigid framework in front of the object glass, and between August 15 and November 19, on which day the driving-screw of the Equatoreal was dismounted and sent to Dublin, eighty photographs of bright star spectra were taken, and though perhaps only sixteen of these are of use for measurement, the preliminary difficulties are in the main surmounted. With a single prism the photographed spectra are 2 inches long between F and H ; and the spectrum of *Vega* was photographed with an exposure of nine minutes, and shows the hydrogen lines up to $\zeta$ (Huggins' notation), though the more refrangible lines are diffuse ; the length of the spectrum from F to $\zeta$ is a little greater than 3 inches.

*Dunsink Observatory.*

There have been considerable changes at this observatory during the year which has just elapsed. On February 20 Sir Robert Ball, then Royal Astronomer of Ireland, was appointed to succeed the late Professor Adams as Lowndean Professor of Astronomy

and Geometry in the University of Cambridge. The vacancy thus caused in the directorship of the Dunsink Observatory was not filled up till October 22, when Dr. Arthur A. Rambaut, who had been assistant to Sir Robert Ball for the last ten years, was elected to the post. Dr. Rambaut, shortly after his appointment, nominated as his assistant Mr. Arthur E. Lyster, of Trinity College, Dublin.

The 15-inch Roberts reflector has been employed during the year for the purpose of obtaining stellar photographs, principally with a view to the determination of parallax. During the year 201 photographs have been obtained, representing 443 exposures, varying from $30^m$ to a few seconds in length. Exposures exceeding $30^m$ are never attempted at this observatory on account of the irregularities of the driving-clock, which entail an uninterrupted watch exceedingly difficult to sustain. The width of the shutter-opening, too, so little exceeds that of the main telescope and pilot together that, except near the pole, it is necessary to interrupt the exposure every fifteen or twenty minutes in order to turn round the dome.

Amongst the plates obtained are included fourteen photographs of the new star in *Auriga*, taken shortly after its first appearance in February, March, and April, and nine photographs in August, September, and October, on the renewal of the star's brightness taking place. As these observations are separated by an interval of six months, and as the star was during each period near one of the apses of its parallactic ellipse, it is hoped that the photographs may serve for a determination of the star's distance. The examination and measurement of the plates have, however, not yet been completed, being delayed by the interruptions consequent on the changes in the observatory staff.

In July and August fifteen photographs of the planet *Mars* were taken, with the view of determining its position with regard to the stars in its neighbourhood. In these photographs a small occulting shutter was used, similar to the shutter described on p. 197 of Dr. Joly's paper, "On Shutters for use in Stellar Photography," in vol. vii. pt. 3 of the *Scientific Proceedings of the Royal Dublin Society*, of which a short notice was published in *Nature* 1891 December 17, p. 167.

With this shutter it is possible to occult any selected object for any desired fraction of the exposure given to the rest of the plate. The shutter is manipulated by means of an electric key from the eye-end of the telescope. In this case the plate was exposed for $10^m$, while the planet's image was allowed to fall on the plate for only $2^s$ at the middle of the exposure. This exposure gave on the Paget prize plates a well-defined disc to the planet, while on most of the plates there are several comparison stars to be found in proximity to it, by which its position can be accurately determined.

During the year 2,576 micrometer measures of stellar photo-

graphs have been made with the Troughton & Simms microscope, presented to the observatory by the Royal Irish Academy. A large proportion of these measures refer to the photographic survey of the star-cluster $\chi$ *Persei*, which was in progress at the date of last report. The results of this preliminary investigation are published in the *Transactions of the Royal Irish Academy*, vol. xxx. pt. iv. This memoir contains, in addition to the measures themselves, an exposition of the method of measurement, a chart of 223 of the principal stars laid down from the measures, and the formulæ of reduction which we were led to adopt.

A further examination of the correction for refraction to measures of stellar photographs by Professor Rambaut will be found in the *Astronomische Nachrichten*, No. 3125. The formulæ there given have been found to be very convenient, especially if, as has been done for this observatory, the values of the quantities $m$, $n$, $\mu$, $\nu$ are tabulated for every minute of hour angle.

During the lunar eclipse of May 11 thirteen photographs of the Moon were taken, showing the progress of the Earth's shadow across the disc. These photographs were exhibited at a meeting of the Royal Dublin Society, and seem to show that for short exposures ($2^s$) the outline of the shadow was to a great extent modified by the nature of the surface upon which it fell, and was very difficult to define, but that with exposures of a minute or so a well-defined circular outline was obtained, although most of the detail on the surface was thereby sacrificed.

There has been no systematic work done with the meridian circle during the year. The place of Holmes' comet was determined with it on November 19, but with the exception of this and a few other observations, the work of this instrument has consisted of time determinations for the service to Dublin and the use of the observatory. There have been in all 366 observations made with this instrument.

The "South" refractor has been in occasional use for observations of *Saturn*, *Jupiter*, and *Mars* when in opposition, for observations of Holmes' Comet, and on the first Saturday of the month it has been put at the disposal of visitors to the observatory.

For the ensuing year Professor Rambaut intends to employ the Roberts reflector for stellar parallax work, as he has done for some time past, while the meridian-circle in connection with the chronograph will be devoted to the investigation of the proper motion of stars.

An account of an investigation of the absorption of heat in the Sun's atmosphere, in which Professor Rambaut has been associated with Mr. W. E. Wilson, will be found in the report of the work of Mr. Wilson's observatory during the past year.

*Glasgow Observatory.*

The operations at the Glasgow Observatory for the past year have consisted mainly in the completion of the "Second Glasgow Catalogue of 2,156 Stars for the Epoch 1890." This catalogue, which is now distributed to the leading astronomers and institutions all over the world, was undertaken with the object of ascertaining the cause of discrepancies which existed between the places of certain stars as given in the first Glasgow Catalogue and the corresponding places of Weisse's Bessel Catalogue. To this list a considerable number of new W. B. stars were added. A comparison was then instituted between the results of these observations and the corresponding places reduced from Baily's Lalande and Weisse's Bessel Catalogues, and when appearances seemed to indicate proper motion other authorities were looked up to confirm it. The results of these researches are given in the list of 192 stars of decided proper motion in the Introduction to the new catalogue. The meteorological work of the observatory has also been carried on as in former years.

*Liverpool Observatory, Bidston, Birkenhead.*

Since the appointment of the new director a very thorough examination of the transit instrument has been made, and notwithstanding its fifty years of constant service, the instrument is still adequate for the purposes in which it is engaged. In connection with a chronograph, constructed on plans supplied by the late Professor Bond, of Cambridge (Mass.), it is proposed to carry on the investigation of the parallax of some binary systems after the plan successfully adopted by Professor J. C. Kapteyn.

The Equatoreal (8 inches) has been, and in the future will continue to be, employed in the systematic observation of comets.

The self-registering meteorological instruments have continued in uninterrupted operation throughout the year, and no change is proposed in their arrangement. The discussion of the meteorological records, accumulated during the last twenty-five years, is contemplated. The digest of meteorological observations made under the superintendence of the late Mr. J. Hartnup in 1889–1891 is now in the press, and the results will shortly be sent to those who are sufficiently interested in meteorological work to apply for a copy.

*Radcliffe Observatory, Oxford.*

During the year the staff has been chiefly employed on the work of the General Catalogue of 6,350 stars for 1890, between the Equator and 115° N.P.D. There only remain 371 of these

stars which require an additional observation. The precessions and secular variations required for the formation of the catalogue have been computed, and the mean places for the different years brought up to the epoch 1890, and this part of the work is now under examination.

The Moon was observed with the transit circle at every opportunity in 1892, but the comparisons of the results with Hansen's Tables have not yet been completed. The places of the Moon observed in the year 1891, showed that the tabular error of Hansen's Tables in longitude had increased to $19''\cdot3$, and the increase had been at the mean rate of $0''\cdot75$ per annum since the end of the year 1863.

Meridian observations of *Mars* and the selected comparison stars were secured on twenty-two nights, being every available night from 1892 June 27 to September 19. The low altitude of the planet affected the definition very considerably, and must to some extent have increased the probable error of the observations.

The zenith distance and transit reductions are completed for 1892.

With the Barclay Equatoreal the following observations have been made:—Seventeen measures of eleven double stars; estimation of the magnitude of *Nova Aurigæ* on thirty-one nights; examination of the Great Nebula in *Andromeda*, and of certain stars for apparent discrepancy of magnitude; some observations of the solar spectrum. The place of Comet *Wolf* was obtained on January 6, and Comet *Holmes* was observed on 1893 January 20.

Five occultations of stars by the eclipsed Moon were secured on May 11, but further observations were prevented by the sky becoming completely overcast.

The meteorological observations have been carried on with the usual regularity.

In the month of September, Mr. F. Bellamy was appointed as assistant at the University Observatory, and his post has been filled up by the appointment of Mr. E. McClellan.

### *Oxford University Observatory.*

The general scope of the observatory work has been unchanged during the past year. The observations for the parallax of about thirty stars, chiefly of the second magnitude, have been at length completed. The results have been published at the expense of the University of Oxford, and have been circulated among various observatories.

The work for the International Star Chart has been prosecuted to the extent permitted by indifferent weather.

An attempt has been commenced for the determination of the parallaxes of various stars in the *Pleiades*, but the position of the group in the heavens renders the work peculiarly difficult. At all events it is to be hoped that the attempt will issue in a

catalogue of the coordinates of all the stars therein up to magnitude 12.

Recently a convenient observatory has been erected, contiguous to the main building, for the exclusive use of university students. This observatory is furnished with two small transit circles, three telescopes, one of which is a reflector of 15 inches aperture, a clock, and various smaller instruments, such as sextants and spectroscopes. In this way the larger instruments in the observatory proper are reserved for research, and more serviceable instruments are provided in their stead for the purposes of instruction. This building is provided with three low-pitched roofs, two of which slide the one over the other, and both of them over the fixed roof of a room provided for the purposes of professorial instruction.

After nineteen years of most able service, Mr. Plummer has taken up his appointment as Director of the Liverpool Observatory. He leaves behind him our grateful recollections of his capabilities and zeal in the past, and our confident expectations that a very useful career lies before him in the future.

### *Temple Observatory, Rugby.*

The usual educational work has been carried on at this observatory during the past year. Mr. Highton has continued the measurement of double stars, and has completed a considerable number of measures. Some little photography has been done on the nebulæ with a 15-inch mirror of 48 inches focus.

### *Stonyhurst College Observatory.*

Some additions have recently been made to the apparatus of the large grating spectrometer, to meet the requirements of photography as applied to small parts of the Sun's disc, such as spots, faculæ, and prominences. The instrument and its heliostat have been already described in the Annual Report of 1891 February. Since then, a 4-inch objective (Jones) has been employed for the solar image, in place of the 6-inch (Alvan Clark) that was originally mounted for the purpose; and the image is now enlarged by a simple concave lens placed near the principal focus of the objective. This arrangement has been found more convenient than an objective of greater focal length; the image is easily brought to a focus by the sliding motion of the enlarger, without shifting the objective, and spots of moderate size are distinctly seen on the slit-plates.

The glass reflectors are now silvered for first surface reflection. Liebig's process, as modified by Mr. Brashear, has been adopted for the purpose, and has given every satisfaction. The exposed positions of the mirrors makes the re-silvering a more frequent necessity than is desirable; but the process is simple,

and the pair of surfaces can easily be renewed in an evening, and made ready for service, if wanted, on the following morning.

The photographs of spot spectra, taken in November and December, number fifteen, all in the green-yellow region. Their evidence, so far, is not conclusive, either for or against real widening of any of the solar lines over spots. But some observers find the same lines, about six in all, widened on all the plates that contain them.

About twenty plates have been exposed to the H K region, with the slit crossing the solar image over areas of faculæ. These show the reversals of H and K, and the reversals are always double, as observed by M. Deslandres and by Professor Hale. On some of the plates the reversals are traceable all along the lines, showing only intensification at the positions of the faculæ; and on three plates exposed to the Sun as a star (*i.e.* without an image on the slit) the same reversals are clearly though not strongly marked. These plates, therefore, confirm the observation of M. Deslandres recorded in the *Comptes Rendus* 1892 July 25.

The drawings of the solar spots, and the measures of the chromosphere and prominences, have been carried on as usual; but the latter observations have been made only on days which showed a fair probability of completing the measures all round the disc without much interruption. Sixty-four complete measures have been made in this way, and the spots and faculæ have been sketched on 160 days, including full drawings and outlines.

The examination of the solar drawings for the year of least activity, 1889, has been greatly interrupted during the course of the past twelve months, but it is now nearly complete. We find twenty-seven separate groups of spots for that year, and 121 groups of faculæ. Of the latter, those which were unassociated with spots were generally small and short-lived, but in number and position, as set out upon the chart, they show two remarkable polar belts in latitudes 72° north and south. The southern belt is much the more pronounced, and in general both spots and faculæ are stronger in number and extent in the southern hemisphere. Six clear cases have been found, in the same year, of small bright faculæ preceding the formation of a spot. And we have apparently conclusive evidence, from seventeen groups of faculæ in the zone between 27° north and south of the Equator, that the rotation-periods of faculæ vary with their latitudes, in strict conformity with Carrington's law for the spots. All these groups have been observed on more than one passage across the visible surface of the sun, and some during as many as four or five rotations.

The night work with the 8-inch Equatoreal has been, almost exclusively, the photography of stellar spectra. The collection of plates, from 1891 September, is a small one. About 180 photographs of 45 stars are available for wave-length measure-

ments, exclusive of many others of a purely experimental purpose. This will probably be the concluding list of operations with the 8-in objective. The new one of 15 inches, purchased with the fund raised to the memory of the late Father Perry, is expected to be in position for a new series of stellar spectra early in March.

### *Dr. Common's Observatory, Ealing.*

During the past year a new 5-foot mirror has been made for the telescope, the disc of glass being that supplied by the Saint-Gobain Glass Co. to replace the first disc.

Very little observational work has been done. The fifth satellite of *Jupiter* has been seen on several occasions. The work on plane mirrors has been carried on, and the method of paper polishing recommended by Foucault tried with an encouraging amount of success.

### *Mr. Crossley's Observatory, Bermerside, Halifax.*

The astronomical work of this observatory has been chiefly the measurement of double stars, the observation of the phenomena of the satellites of *Jupiter* and *Saturn*, the occultation of stars by the Moon, and transits of clock stars for time. The usual meteorological observations at 9 A.M. and 3 P.M. have also been made, and reports sent to the Registrar-General, Mr. Symons, and the local sanitary department. As Mr. Crossley has withdrawn from active astronomical work, he has decided to dispose of the 3-foot reflector and dome.

### *Wolsingham Observatory* (*Rev. T. E. Espin's*).

The usual spectroscopic zone-work was somewhat interrupted in the spring by the attention given to the *Nova Aurigæ*. In zones $+55°$ and $+56°$, 116 new third-type stars were, however, detected. Amongst these one star (D.M. $+55°$. 1870) was suspected of variability; but Professor Pickering has found no variation from the Harvard photographs. In the autumn it was determined that the telescope should be entirely devoted to the revision of double stars in connection with the forthcoming edition of *Celestial Objects for Common Telescopes*, but it was not till October 1 that sufficient practice had been made to warrant the commencement of actual measurements. Between this and the end of the year 847 measures were made, observations being often carried on for 12 hours consecutively, and on one favourable night for $13\frac{1}{2}$ hours, on account of the urgency of the work. Moreover, during the measurements new companions were in many cases detected, closer than those already known. Thus $\Sigma$ 306 has three comites

nearer than the one measured by Dembowski; while Σ 994, H V. 66, β *Camelopardi*, were found to be more closely double. Generally the new comites are difficult objects, and are only measured with much difficulty.

The daily readings of the meteorological instruments have been continued during the year.

### *Dr. Huggins' Observatory, Upper Tulse Hill, S.W.*

The work of this observatory during last spring was chiefly devoted to observation—both visual and photographic—of *Nova Aurigæ*. The results have been published in the Royal Society's Proceedings.

During the summer and autumn alterations were in progress in the equipment of the observatory; these have now been completed, and work has been resumed.

### *Rousdon Observatory, Lyme Regis (Mr. C. E. Peek's).*

Observations of "long-period variable stars" have been continued during 1892. The year has been, on the whole, favourable for astronomical work, 166 nights having been available for observations: 502 determinations of magnitudes were obtained, this being considerably in excess of any of the previous six years' work. The working list includes twenty-four objects, chiefly long-period circumpolar variables, with a few, less-favourably situated, but specially interesting objects. Among the latter is *Nova Aurigæ*, which has been been examined with great attention. The nebulous and ill-defined appearance of this variable has been noticed by several observers, and has drawn special attention to the unusual characteristics of the images of many of the variables as compared with ordinary non-variable stars. This peculiarity has also been observed here with regard to several other stars for several years past.

The usual observations of clock stars have been taken.

Instrument in use, 6·4-inch equatorial refractor. Powers 34, 80, and 132.

### *Dr. Isaac Roberts's Observatory, Crowborough Hill, Sussex.*

Photographs of stars, planets, nebulæ, and clusters of stars have been taken, as frequently as practicable, during the year ending 1892 December 31, but the number of nights sufficiently clear for long exposures of the plates has, I think, been below the average that might be expected in this locality. Moonlight also diminishes largely the number of nights that would, in its absence, be suitable for photographic work.

One hundred and twenty-two photographs, with exposures from 30 minutes to 4 hours, were obtained during the year, and also many others with shorter exposures. Of the plates with

long exposures 18 were taken in March, 26 in April, 14 in October, and 15 in December.

Ten plates of the eclipse of the Moon on May 11 were taken, with exposures from 4 seconds to 10 minutes each, and upon them the phases are well recorded.

Following is a list of the regions in the sky which have been photographed with long exposures during the year, and the plates are available for reference when required. Those marked * have been enlarged and presented to the Society, and I am engaged in preparing for publication about fifty selected photographs, with the necessary descriptive matter to accompany them, so as to make them available, at a nominal price, for the use of astronomers.

The coordinates given are those for about the centre of the plates, each of which covers 2° by 2° of the sky.

| | R. A. h m | Decl. ° ′ | Expos. m |
|---|---|---|---|
| Neb. near β Andromedæ | 1 3½ | N. 35 10 | 60 |
| *Comet Holmes | 0 43 | „ 37 24 | 75 and 30 |
| Neb. ♅ I. 151 Piscium | 1 19 | „ 9 0 | 90 |
| Cl. 103 M. Cassiopeiæ | 1 26 | „ 60 9 | 60 |
| Neb. ♅ I. 100 and II. 4 Ceti | 1 27 | S. 7 30 | 60 |
| Cl. 74 M. Piscium | 1 31 | N. 15 15 | 90 |
| Cl. ♅ VI. 31 Cassiopeiæ | 1 38½ | „ 60 43 | 60 |
| Neb. Trianguli | 2 31 | „ 29 41 | 60 |
| Cl. 34 M. Persei | 2 35 | „ 42 20 | 60 |
| Neb. 77 M. Ceti | 2 37 | S. 0 27 | 90 |
| Cl. ♅ VI. 25 Persei | 3 7½ | N. 46 51 | 54 |
| Cl. Camelopardi | 3 56½ | „ 69 30 | 60 |
| Neb. Star H. IV. Tauri | 4 3 | „ 30 30 | 140 |
| Plan. Neb. ♅ IV. Eridani | 4 10 | S. 13 2 | 60 |
| Neb. ♅ I. 217 Aurigæ | 4 23 | N. 35 3 | 90 |
| Cl. 38 M. Aurigæ | 5 21½ | „ 35 44 | 60 |
| *Nova Aurigæ | 5 24 | „ 30 23 | 5 to $3^h$ |
| *Crab Neb. 1 M. Tauri | 5 29 | „ 21 57 | ... $3^h$ |
| Cl. 35 M. Geminorum | 6 2 | „ 24 21 | 55 |
| Sirius | 6 40 | S. 16 34 | 4 to $2^h$ |
| Neb. ♅ I. 163 Sextantis | 10 0 | „ 7 12 | 60 |
| Regulus | 10 2 | N. 12 29 | 90 |
| Neb. 99 M. Virginis | 12 13 | „ 13 0 | 90 |
| Neb. 95 M. Leonis | 10 40 | „ 12 18 | 90 |
| Neb. ♅ I. 13 Leonis | 11 0 | „ 0 32 | 90 |

| | R. A. h m | Decl. ° ′ | Expos. m |
|---|---|---|---|
| Neb. 66 M. Leonis | 11 14 | N. 13 40 | 90 and 4h |
| Search for Planet beyond Neptune from | 11 24 | „ 0 0 | 90 |
| to | 12 12 | „ 6 0 | 90 |
| Neb. 98 M. Virginis | 12 8 | „ 15 29 | 90 |
| Neb. 61 M. Virginis | 12 16 | „ 5 3 | 90 |
| Neb. 84 and 86 M. Virginis | 12 20 | „ 13 30 | 90 |
| Neb. 85 M. Comæ Berenicis | 12 20 | „ 18 46 | 90 |
| Neb. 41 M. Virginis | 12 24 | „ 8 35 | 90 |
| Neb. 88 M. Virginis | 12 26½ | „ 15 0 | 90 |
| Neb. 87, 89, and 90 M. Virginis | 12 28½ | „ 13 26 | ... 4h |
| Neb. 54 M. Virginis | 12 36 | „ 12 16 | 90 |
| Neb. 94 M. Canum Venaticûm | 12 46 | „ 41 42 | 90 |
| Glob. Cl. 53 M. Comæ Berenicis | 13 7 | „ 18 44 | 60 |
| Neb. 63 M. Canum Venaticûm | 13 11 | „ 42 35 | 50 |
| Neb. H I. 34 Virginis | 13 32 | „ 9 26 | 90 |
| Cl. 3 M. Canum Venaticûm | 13 37 | „ 28 55 | 60 |
| Neb. 101 M. Ursæ Majoris | 13 59½ | „ 54 52 | 90 and 200 |
| Neb. H I. 215 Draconis | 15 3½ | „ 56 10 | 90 |
| Cl. 5 M. Lyræ | 15 13 | „ 2 28 | 90 |
| Cl. 12 M. Ophiuchi | 16 41½ | S. 1 45 | 60, 105, and 2h |
| Cl. 14 M. Ophiuchi | 17 32 | „ 3 11 | 90 |
| Cl. 26 M. Clyp. Sobieskii | 18 39 | „ 9 30 | 90 |
| Cl. H I. 47 Aquilæ | 18 47 | „ 8 50 | 60 and 120 |
| Cl. *h* 2024 Aquilæ | 18 49 | N. 10 13 | 60 |
| Cl. 56 M. Lyræ | 19 12½ | „ 30 0 | ... 3h |
| Cl. 52 M. Cephei | 23 19 | „ 61 1 | 60 |
| Cl. 71 M. Sagittæ | 19 49 | „ 18 30 | 90 |
| Cl. H I. 103 Delphini | 20 29 | „ 7 3 | 60 and 3h |
| Neb. H V. 15 Cygni | 20 46½ | „ 30 15 | ... 4½h |
| Neb. H V. 14 Cygni | 20 52 | „ 31 4 | 120 |
| Neb. H I. 192 Cephei | 20 57 | „ 54 9 | 90 |
| Neb. H I. 53 Pegasi | 22 32 | „ 33 52 | 219 |
| *Neb. H I. 55 Pegasi | 23 0 | „ 11 46 | ... 4h |
| *Cl. H VI. 30 Cassiopeiæ | 23 52 | „ 56 8 | 60 and 90 |

### *Mr. W. E. Wilson's Observatory, Streete, Co. Westmeath.*

The remounting of the 2-foot reflector by Sir H. Grubb was completed about February last. A considerable number of photographs of stars have been taken, principally with the view of getting the telescope in final adjustment.

Some photographs were taken in the autumn of *Jupiter* and his satellites with the photographic photometer in order to determine the relative albedo of the planet and his moons. The results will shortly be laid before the Society.

The mirror was sent to Sir H. Grubb in November in order to make it a better fit in its cell.

A paper was read by myself and Professor Rambaut before the Royal Irish Academy in May on "The Absorption of Heat in the Solar Atmosphere." A copy of this has been sent to the library of the Society. The large siderostat kindly lent by the Royal Society to carry on experiments on solar radiation has arrived, and will be erected this coming spring.

### *Hong Kong Observatory.*

During the past year the time-ball was dropped daily at 1 P.M. The transit observations were made with a new chronograph by Sir H. Grubb, of Dublin, which works exceedingly well. Some observations of eclipses and shooting stars were also made.

Absolute magnetic observations were made monthly.

Local, continuous, and hourly meteorological observations were made the same as in previous years. Reports were received from about forty stations on shore, a number of which were inspected during the year. Over 500 extracts of log-books of ships having encountered bad weather were copied. Daily weather-maps for the years 1888 to 1892 inclusive are ready, and are being used in the investigation of orbits of typhoons in those years. Daily weather reports and telegraphic storm-warnings were issued as usual. A number of instruments were verified.

Three years' hourly readings of tides from trace on Sir W. Thomson's automatic tide-gauge were finished, and the first two harmonically analysed by Mr. Roberts in London. These records have since been discontinued.

The eighth annual volume was issued last spring, and the ninth volume is nearly ready for press.

Lectures on spherical and practical astronomy were delivered to the staff.

### *The Madras Observatory.*

During 1892, as for several years past, observations other than those required for the efficient maintenance of the time service have been entirely subordinated to the work of publication. During the year two volumes of the *Madras Meridian Circle Observations* and one volume of *Meteorological Results* have been published, and at the close of the year two other volumes were well advanced. The *Meridian Circle Observations* are now in type to the close of 1878, but as the observations were continued till 1887, it will probably be nearly two years more before the final catalogue can be issued. In the early part of the year the Officiating Government Astronomer made a series of comparative observations at Madras, Kotagiri, on the Nilgiris, and Kodaikanal, on the Palani Hills (7,500 feet above sea level), with the object of testing their relative merits as sites for the proposed new observatory. The general result of the observations was that Kodaikanal was far superior to either of the other two—a result since confirmed by meteorological observations.

The future of the observatory as to position, equipment, and staff is still undecided, but there seems to be good reason to hope that something will be done before long to put matters on a more satisfactory footing.

### *Melbourne Observatory.*

The astronomical work of the Melbourne Observatory during 1892 has consisted chiefly of meridian observations and astrographic operations. Very little extra-meridional work has been done, either with the great telescope or the smaller equatoreals, beyond occasional planet or comet observations.

As regards the meridian work, the places of 3,181 stars in R.A. and 1,861 in N.P.D. have been obtained, and a list of 913 guiding-stars, for use at the Tacubaya Observatory in connection with the astrographic operations, was completed in March last and forwarded to its destination.

Considerable progress has been made with the astrographic work during the year, although it has been much hindered by somewhat unusually cloudy weather in Melbourne during the spring and summer. It is found that photographs, to fulfil the necessary conditions, cannot be obtained unless the sky is absolutely clear and free from moonlight; the slightest trace of the latter diminishes the photographic magnitudes of star images on the plates in a very marked manner. Only those nights, therefore, are used which are quite clear, and on which there is no moon. The number of Catalogue plates obtained up to date is 548. No work has yet been done with Chart plates.

Owing to large retrenchments in colonial expenditure, the

annual grant to the observatory has been seriously reduced since June, and the staff has been permanently reduced by the retirement, on pension, of the two senior assistants, Messrs. White and Moerlin. Mr. Baracchi, the third assistant, has taken up the duties of these two officers as far as possible, and, although the work of the establishment has necessarily to be considerably curtailed, it will affect the routine operations chiefly. The meridian and astrographic work will go on as usual, as will the magnetographic and meteorological work; the latter, however, being somewhat reduced in its less important details.

Regular work with the great telescope must be given up for the present, and little time can be given to any but the most important extra-meridian observations.

The routine work of the observatory, which includes meteorological and magnetic observations, distribution of time by signals and telegraph, rating chronometers, testing barometers, thermometers, linear measures, &c., and tidal observations, has been carried out during the year as usual.

### *Natal Observatory, Durban.*

The principal work of the past year has been the observation of the opposition of *Mars* during July and August, and, as the weather was fairly favourable, it is to be regretted that the observatory did not possess the requisite instruments necessary for carrying out the observations according to the schemes suggested by either Professor Newcomb or Mr. Stone.

With the view of supplying some data in the event of unfavourable weather at the other southern observatories, care was taken to obtain the best results that could be obtained with the limited means at the observatory.

The meridian observations were made with the transit instrument firmly clamped in one position the whole evening, the difference between the declination of *Mars* and all available stars being measured with the micrometer. The field of view of the micrometer is rather more than one degree, the instrument being provided with double slipping pieces, and all stars brighter than $7\frac{1}{2}$ mag. which transited within half an hour of the planet were observed, usually five to eight each evening.

As a rule, a bisection was made as the star crossed each of seven vertical wires ($20^s$ apart), whilst the planet was observed at the same wires, north and south limbs being taken alternately at each wire. Generally, each star was observed on seven or eight successive nights. In all observations were obtained on thirty-eight nights.

Observations for diurnal parallax were made with the equatoreal, which was kept firmly clamped in declination, whilst

differences in right ascension were obtained by the observed transit over seven wires of the planet and selected star. In all sixty-two sets of morning and evening observations were obtained.

Further progress is being steadily made in preparing for the press the Memoirs *On the Reduction of the Lunar Observations* and *The Theory of the Perturbations produced by the Planets*; and though there is much delay from the heavy pressure of official duties, and especially the routine work consequent on the absence of any qualified assistance, it will not be long before the last pages of one, if not of both, papers are written out ready for publication.

### *Sydney Observatory.*

At Sydney Observatory the year 1892 has been cloudy and wet, and, like its predecessor, generally unfavourable for astronomical observations. From May 10 to December 22 Mr. Lenehan was away on sick leave, and Mr. Sellors had to take his place, which has seriously reduced the number of measures of double stars. Owing mainly to this it was found impossible to take special observations of *Mars* during opposition, and the weather was so unfavourable that it was impossible to get good views of the features of the planet except on two nights when the conditions were fairly good, but even then nothing was seen of the so-called "canals."

The difference of longitude between Sydney and Brisbane has been determined and found to be in very satisfactory agreement with two previous determinations. The observations and telegraphic comparisons were made from February 24 to March 1. In connection with this, Mr. R. G. McDawall's personal equation was determined during three nights.

With the transit circle 1,001 transits in R.A. have been taken, comprising 597 stars in R.A. only, and 404 in R.A. and N.P.D. These belong to the photographic zone.

Azimuth has been determined 128 times; Collimation, 272; Level, 341; Nadir, 351.

Comets Swift and Biela were observed, the former on three and the latter on six nights.

The computations of transit work have been completed up to the end of 1892, and recomputations of previous transit observations brought up to the end of 1890. The results of transit observations, with catalogues for 1879 and 1880, are printed, and 1881 is in progress. A full account of the New South Wales transit of *Venus* observations in 1874, illustrated by forty-one coloured diagrams, photographs, &c., has been published.

Meteorological results for the years 1880 to 1884 and 1890 have been printed. Rain and river results for 1890 have been

printed and published, and those for 1891 have been printed but not yet distributed.

A new edition of *Physical Geography and Climate* has been published; also some pamphlets, making in all 1,600 pages. A fully-illustrated description of the Star Camera has also been published.

A number of bromide enlargements of stellar and lunar photographs have been made, and with such good results that it is obvious that many astronomical photographs require to be treated in this way to see them to advantage. Some cheap printing process is wanted for multiplying these enlargements, which are real aids to the study of photographs.

Several photographs of Swift's Comet, one of which was presented to the Royal Astronomical Society, were taken in March, with a result that was not expected. The comet was shown by them to have eight ribbon-like rays, which were all invisible with the large equatoreal, even when the camera had revealed their existence. Some photographs have been taken of Brooks' Comet, which show the tail, but no rays like those of Swift's Comet. Four photographs of the latter show the rays. Six photographs of the Moon during the total eclipse of November 5 were taken.

During the year ninety-three nights were partially or wholly good for star-catalogue plates, and thirty-seven nights cleared enough to get a test object taken, and then clouded over. 465 star-catalogue plates were taken, 136 of test objects, 10 of comets, and 12 of *Mars*, making a total of 623. The year thus appears to have been better than 1891, during which only fifty-two nights were partially or wholly good. Three *réseaux* have been obtained from M. Gautier of Paris, but only one of these was free from pin-holes. The actual measurement of the plates has not yet been commenced.

Some experiments are in progress as to the value of photography in determining a comet's position relative to stars. Five minutes' exposure gives a good image of Brooks' Comet, and images of stars slightly elongated in the direction of the comet's motion, but capable of exact measurement.

The weather chart service has been maintained and two editions published daily. Close attention has been given to the investigation of weather conditions, and some results have been published, especially a study of the anticyclonic systems which pass over Australia and rule our weather.

### *Mr. Tebbutt's Observatory, The Peninsula, Windsor, New South Wales.*

The year 1892 was characterised by a large proportion of cloudy nights, and yet much excellent work was done. The local time was determined on 159 nights, the number of stars observed

for this purpose with a declination not exceeding 40° being 908. The number of separate determinations for the level, collimation and azimuth errors of the transit instrument were 378, 43 and 162 respectively. There has been only one adjustment of the instrument, and that for level, during the year. The errors have been subject to small fluctuations only, and the rate of the standard sidereal chronometer has been satisfactory. The following is a statement of the extra-meridian work with the 8-inch and $4\frac{1}{2}$-inch equatoreals.

Occultations of stars by the Moon were observed, comprising twenty-six disappearances at the dark and six at the bright limb, and six reappearances at the dark and seven at the bright limb. The occulted stars have, with the exception of one, been all identified, and they are nearly all stars whose positions have been well determined. I have again to acknowledge the co-operation of Mr. R. T. A. Innes, F.R.A.S., of Sydney, who has kindly sent me monthly his prediction calculations of the occultations of *Nautical Almanac* stars.

The following double stars were measured with the 8-inch telescope:—*p Eridani*, *h* 4373, *a Crucis*, *γ Centauri*, *γ Virginis*, *β Muscæ*, *h* 4634, *α Centauri*, *π Lupi*, *Lacaille* 6477, *ρ Ophiuchi*, 36 *Ophiuchi*, *Brisbane* 6556, and *γ Coronæ Australis*.

Twenty filar-micrometer comparisons of *Mars* and *ι Aquarii* were obtained with the 8-inch equatoreal on November 4. The objects were not seen till after the conjunction in R.A., but it was quite obvious that no occultation could have taken place at the Observatory. The star forms one of Herr Berberich's list in No. 3073 of the *Astronomische Nachrichten*.

Swift's Comet I. 1892 was observed on March 10, 21, 22, 26; April 9, 10, 11, 12, 13, 14, 15, 16, 22, 23, 30; May 1, 2; the number of comparisons being 246, and that of the comparison stars 29. Winnecke's periodical Comet was picked up on June 12, but as it was then in pretty high north declination, no observations were attempted. After its conjunction with the Sun, however, it was observed on July 17, 19, 20, 21, 22, 23, 24, 27, 28, 29; August 2, 3, 15, 23, 25, 26, 27; September 16, 17, 18, 20, 22, 26, 27. 248 comparisons were made, in which twenty-nine comparison stars were employed. Holmes' Comet was observed on November 13, 15, 18, 19, 20, 22, 23, 24. The observations comprise fifty comparisons and five comparison stars. Brooks' Comet of August 28 was observed on November 28, 29; December 8, 9, 12, 13, 14, 15, 20, 21, 23, 24, 28, 29, the number of comparisons being 177 and that of the comparison stars 23. Observations were continued after the close of the year, but these will properly be accounted for in the Report for 1893. Tempel's Comet II. 1867 was searched for between R.A. $17^h\ 30^m$ and $18^h\ 50^m$, and the parallels of twenty-five and thirty-two degrees south declination on June 19. Although the sky was brilliantly clear and the Moon absent no trace of the Comet could be found.

A few observations of the phenomena of *Jupiter's* satellites were made, and a few estimations were also obtained of the magnitudes of $\eta$ *Argûs* and *R Carinæ*. The meteorological observations have been carried on as usual, and the Abstracts of Results for 1886, 1887, 1888, 1889, and 1890 widely distributed. The whole work of observation, both in the astronomical and in the meteorological departments, and the greater portion of the reductions, have been done by the proprietor himself. All the instruments remain in good order, and the library has been greatly enriched by valuable donations.

## Notes on some Points connected with the Progress of Astronomy during the past Year.

[In the present Report an attempt has been made to give a list of discoveries during the year, not only in the cases of minor planets and comets, but those of double stars, variable stars, &c. It is probable that, on this occasion, these lists are far from complete, and it would very materially assist the Secretaries if discoverers themselves would furnish accurate information for future Reports, and corrections of any inaccuracies or omissions in the present.]

### *Discovery of Minor Planets.*

The number of minor planets has been increased by twenty-nine during the past year, this rapid increase being due to the introduction of photography as a means of search, which has proved very effective in the hands of Herr Wolf and M. Charlois. The following is the list of discoveries:—

| No. | Name. | Date of Discovery, 1892. | Discoverer. | Place of Discovery. |
|---|---|---|---|---|
| 324 | ... | Feb. 25 | Palisa | Vienna |
| 325 | Heidelberga | Mar. 4 | Wolf | Heidelberg |
| 326 | Tamara | 19 | Palisa | Vienna |
| 327 | Columbia | 22 | Charlois | Nice |
| 328 | Gudrun | 18 | Wolf | Heidelberg |
| 329 | Svea | 21 | „ | „ |
| 330 | Ilmatar | 19 | „ | „ |
| 331 | ... | Apr. 1 | Charlois | Nice |
| 332 | Siri | Mar. 19 | Wolf | Heidelberg |
| A | Badenia | Aug. 22 | „ | „ |
| C | Roberta | Sept. 1 | Staus | „ |
| D | ... | 19 | Charlois | Nice |
| E | ... | 22 | „ | „ |
| F | ... | 25 | „ | „ |
| G | Dorothea | 25 | Wolf | Heidelberg |
| H | ... | 25 | „ | „ |
| J | ... | 25 | „ | „ |

| No. | Name. | Date of Discovery, 1892. | Discoverer. | Place of Discovery. |
|---|---|---|---|---|
| K | ... | Oct. 17 | Wolf | Heidelberg |
| L | ... | Aug. 23 | „ | „ |
| M | ... | Nov. 15 | Charlois | Nice |
| N | ... | 15 | Wolf | Heidelberg |
| O | ... | 23 | Charlois | Nice |
| P | ... | 25 | „ | „ |
| Q | ... | 28 | „ | „ |
| R | ... | 28 | „ | „ |
| S | ... | Dec. 8 | „ | „ |
| T | ... | 9 | „ | „ |
| U | ... | 14 | „ | „ |
| V | ... | 16 | Wolf | Heidelberg |

In consequence of some tendency to confusion in the numeration of new planets, it has been decided to provisionally distinguish new discoveries by letters assigned in the order in which the news of the discovery reaches the Centralstelle. Permanent numbers will be subsequently assigned to those planets of which a sufficient number of observations is available to satisfactorily determine the orbit.

In the above list B is missing since the planet thus designated was discovered to be identical with (163) *Erigone*.

According to Berberich, No. 324, when in opposition in perihelion, will be brighter than the 8th magnitude. The tardy discovery of such a conspicuous member of the group is remarkable.

305 has been named *Gordonia*, 307 *Nike*, 308 *Polyxo*, 310 *Margarita*, 311 *Claudia*, 312 *Pierretta*, 320 *Katharina*, 322 *Phœo*, 323 *Brucia*.

In the case of photographic discoveries the date given is that of the earliest photograph on which the planet appears. It was in many cases not noticed on the plate till considerably later, which accounts for the departures from chronological order in the column headed "Date of Discovery."

The discoveries are all by photography with the exception of Nos. 324, 326, 327, 331.

Permanent numbers have just been assigned to planets A to L as follows:—A 333, C 335, D 336, E 337, F 338, G 339, H 340, J 341, K 342, L 334, M 344, N 343. A. C. D. C.

## *The Comets of* 1892.

Including the periodical comet of Winnecke, seven comets have been discovered during the year.

(*a*) Discovered by Professor Lewis Swift, of Rochester, New

York, on the morning of 1892 March 7, the comet at the time having considerable southern declination. It was sufficiently bright at the date of discovery to be visible to the naked eye, and although there was no great increase in the theoretical brilliancy, it nevertheless became a very conspicuous object in the morning sky, the length of the tail being estimated by various observers at 10°, 11°, and even 20°, while the nucleus shone as a star of the third magnitude. Very successful photographs were taken at the Lick Observatory by Professor Barnard, which exhibited "creases, knots, and bends in the streams of luminous matter, apparently flowing out from the head and forming the tail." The diminution of brilliancy from the head to the extremity of the tail was not uniform.

The course of the comet was through *Aquarius*, *Pegasus*, and *Andromeda*, and observations pursued through several months (it was seen at Bordeaux on November 20) showed that the path of the comet deviated sensibly from the parabola. Dr. Berberich found that the observations are best represented by an ellipse of about 2000 years' period; and it is possible that the slight difference from parabolic velocity was produced by an approach to *Saturn* about 1887, but this point cannot be decided till the definitive elements have been computed.

(*b*) On March 18, Mr. Denning, of Bristol, detected a faint comet near δ *Cephei*, and, as the elements have shown, at a very considerable distance both from the Earth and Sun. Owing to these relations the comet remained small and inconspicuous, but observations have been possible through a considerable period, and in large telescopes the object is probably still visible. The observations, as at present discussed, do not exhibit any signs of ellipticity in the orbit.

(*c*) A return of the comet of Winnecke. Dr. Spitaler's long search for this comet, continued at favourable opportunities since 1891 February, was rewarded by success on March 18, the comet then being more than three months before perihelion passage. The position predicted by Dr. Haerdtl, whose admirable researches on the theory of this comet are well known, was in error only half a minute in the arc of a great circle, and this close agreement between theory and observation diminishes the probability that a faint cometary object, seen by Dr. Spitaler more than a year previously, was really Winnecke's comet, since this suspicious object was some twelve minutes from the path computed by Dr. Haerdtl.

Observations were possible in the Northern Hemisphere till June, the brilliancy constantly increasing, but the position for observation less favourable as the comet approached the Sun. On emerging from the Sun after perihelion passage, the comet was more favourably situated for observations in the Southern Hemisphere, where it has been well observed.

(*d*) On August 28 Mr. Brooks, of New York, detected a faint telescopic comet in Gemini, some four months before its

perihelion passage. The comet was, therefore, increasing in brilliancy, and before the end of the year became a conspicuous object with a well-developed tail. The great southern declination, however, into which the comet has moved, has prevented the accumulation of observations in the Northern Hemisphere. A parabolic orbit represents the path of the comet with great accuracy.

(*e*) The discovery of this comet is particularly interesting, owing to the fact that it was detected on a photographic plate, and is the first so discovered, if we except the somewhat doubtful record of a comet on plates exposed during a solar eclipse. The discovery is due to Professor Barnard, who on October 12 exposed a plate for a considerable time to the neighbourhood of *a Aquilæ*. On developing, a trail was observable, which was conjectured to have been impressed by a comet, and on the first favourable opportunity the comet was easily picked up, about two degrees from the place marked on the photographic plate. The elements also are interesting, since pronounced deviation from parabolic motion was at once evident. With elements computed from only five days' observations it was impossible to represent the middle longitude within half a degree; and, further, the elements showed great similarity to those of the periodic comet of Wolf. Dr. Schulhof called attention to the extreme probability of the two comets having formed part of one body, presenting a similar case to that of Biela and Brooks' comet, 1889, V. This conjecture is still further strengthened by the application of Tisserand's well-known criterion, where, following the usual notation, we have:—

$$\frac{1}{a} + \frac{2\sqrt{A_J}}{R^2_J}\sqrt{p\cos i} =$$

| | |
|---|---|
| for Comet Barnard | 0·495 |
| „ „ Wolf, 1891 | 0·497 |
| „ „ „ 1875 | 0·492 |

With a particular value of the period, not greatly different from that assigned by Dr. Schulhof, it would be possible that the comet should be near *Jupiter* in 1875, when Wolf's comet was also within the sphere of that planet's attraction; but the close agreement of these figures seems to indicate that the orbit is very exact, and that such alteration of the period is not permissible. This would indicate that the separation of the two bodies was probably earlier than 1875, but the decision of this point must be left till the orbit is definitely determined. It is unfortunate that the feebleness of the comet has prevented a very long series of observations. It was seen at Nice at the beginning of December, and may still be within the reach of the largest telescopes.

(*f*) On November 6 Mr. Holmes, of London, discovered a

bright comet in the constellation *Andromeda*, and the same comet appears to have been independently discovered in Queensland on November 9 by Mr. Davidson. The comet is described by the discoverer as 5′ in diameter, and bright enough to be seen by the naked eye. The greatest theoretical brilliancy occurred in the latter portion of September, when the comet should have been rather brighter than on November 6, and well situated for observation in the Northern Hemisphere. It is therefore remarkable that so bright an object was not sooner detected, but this comet seems to have exhibited greater fluctuations in brilliancy than any other comet. Dr. Palisa has telegraphed that the present appearance of the comet (January 18) is that of a star of the eighth magnitude surrounded by a nebulosity extending not more than twenty seconds in diameter. Since this outburst has occurred, after the comet had become invisible in ordinary telescopes, it is not improbable that a similar outburst occurred shortly before November 6. Such variations of character would explain the non-appearance of the comet on the photographic plates that have been certainly exposed to the sky in the situations the comet was occupying, for though suspicions have been entertained of the photographic impression of the comet, yet, when submitted to exact calculation, the deduced position from the photographic plate has not given an entirely satisfactory result.

Such variations of brilliancy would explain the fact that the comet had not been seen at some earlier return, for the orbit has proved itself to be one of short period, and it is probable that the comet has made more than one return to the Sun in practically the same orbit. Subsequent inquiry has shown that it is not impossible that Holmes' comet belongs to the same family as that of De Vico, 1844, I.

(*g*) The last cometary discovery of the year was effected by Mr. Brooks, who perceived a bright comet in the constellation of *Boötes* on the morning of November 19. Its steady increase in brilliancy, coupled with its northerly motion, made it a tolerably easy object for observation. Since the perihelion passage falls in 1893, this comet will appear in the catalogues of that year. W. E. P.

### *The Fifth Satellite of Jupiter.*

The astronomical event of the year is undoubtedly the discovery of a fifth satellite to *Jupiter*, made at the Lick Observatory, California, on Sept. 9, at midnight, by Professor E. E. Barnard, who, while carefully examining the neighbourhood of *Jupiter* with the 36-inch, detected "an exceedingly small star" close to the planet and near the third satellite, which he at once suspected to be a new satellite, a suspicion soon verified. The discovery was the result of a systematic search for new objects instituted by Professor Barnard.

The satellite has since been frequently observed and measured at the Lick Observatory. Professor Barnard has occasionally been able to follow it to within 8″ of the planet's limb, but remarks that, examining it under the best conditions with a high power, he has never seen it other than as a star, nor has he been able to catch the slightest glimpse of its shadow when in transit. In all his later observations a piece of smoked mica has been used in front of the eye-lens to dull the light of *Jupiter*, the planet and satellite then being readily seen at the same time. Nearly all his observations were made at east elongation.

The following elongations were observed among others :—

September 10, $20^h\ 49^m{\cdot}0$, east elongation.

October 21, $17^h\ 2^m{\cdot}8$, east elongation.

October 23, $16^h\ 49^m{\cdot}0$, east elongation.

From the first two a period of $11^h\ 57^m\ 20^s{\cdot}5$ results.

From an elongation on October 28 the period was computed as $11^h\ 57^m\ 17^s$.

The mean of ten measured east elongations, reduced to the mean distance of *Jupiter*, between September 10 and October 28 is $48''{\cdot}10 \pm 0''{\cdot}011$, while the mean of four (including a discordant one) west of the planet gives $47''{\cdot}42 \pm 0''{\cdot}042$, the probable error of a single observation being $\pm 0''{\cdot}11$ and $\pm 0''{\cdot}17$. These two values represent a distance from *Jupiter's* centre of 112,520 miles and 110,930 miles respectively.

The west elongations are about 1″ less than the eastern, so that the orbit is apparently elliptic. The measures for latitude seem to show that the satellite's orbit lies sensibly in the plane of *Jupiter's* equator, which would signify that it is not a recent addition to the Jovian family.

The fifth satellite has also been observed at a few other observatories possessing instruments of sufficient calibre. Professor Stone has seen and measured it with the 26-inch at the University of Virginia. At Princeton it was observed on several occasions between October 10 and 29 by Mr. Reed, Professor Young's assistant, who, however, was unable to obtain any complete set of measures embracing both sides of an elongation. His observations point to a period of $11^h\ 57^m\ 23^s$, with an error probably less than 10 secs. Mr. Reed stated that he found it an easier object than *Ariel*, the inner satellite of *Uranus*, which reverses the experience of Professor Hough, who saw it with the $18\frac{1}{2}$-inch at Evanston, Illinois, and reported it much more difficult than *Ariel* and *Umbriel*. The satellite was also observed with Dr. Common's 5-foot reflector at Ealing, on five occasions between October 18 and December 26, but no measures are reported. On December 13, at $6^h\ 55^m$, Mr. Taylor observed it in conjunction with the first satellite, which was below the fifth. On December 25 and 26 it was seen when at W. elongation between $5^h$ and $6^h$ G.M.T.

A full account of the discovery was given by Mr. Barnard in the *Astronomical Journal*, No. 275, 1892 October 4, together with

all his micrometer measures obtained from September 9 to 16. Later details were given in a paper communicated to the R.A.S. meeting 1892 November 11.

Mr. Marth, in his second provisional ephemeris (1892 December 1 to 1893 January 28), has adopted $11^h\ 57^m\ 37^s$ as the period. A. E.

## *Nova Aurigæ.*

On February 2 the following circular was issued from the Royal Observatory, Edinburgh :—

"Yesterday an anonymous postcard was received here, bearing the following communication :—*Nova* in *Auriga*. In Milky Way, about two degrees south of $\chi$ *Aurigæ*, preceding 26 *Aurigæ*, fifth magnitude, slightly brighter than $\chi$ *Aurigæ*.

"At $6^h\ 8^m$ G.M.T. the star was easily found with an opera-glass. It was of a yellow tint and of the sixth magnitude, being equal to 26 *Aurigæ*. Examined with a prism between the eye and the eye-piece of the 24-inch reflector, it was immediately seen to possess a spectrum very like that of the *Nova* seen in 1866. The C line was intensely bright ; a yellow line about D fairly visible ; four bright lines or bands were conspicuous in the green ; and, lastly, a bright line in the violet (probably H$\gamma$) was easily seen. A telegraphic notice was sent to Greenwich in the afternoon, and, later on, when the true nature of the object was recognised, to Kiel, for general distribution. The star was photographed last night at Greenwich. Its place for 1892 is $5^h\ 25^m\ 3^s + 30°\ 21'$. It does not occur in the Bonn maps."

Dr. Thomas D. Anderson, the author of the postcard to Professor Copeland, is an amateur astronomer living in Edinburgh, and he discovered the new star by means of a star-atlas and a small pocket-telescope. In a letter to *Nature*, 1892 February 18 (p. 365), he announced that the star was visible as of the 5th magnitude for some days before the postcard was despatched to Professor Copeland. The previous history of the star was, by singularly good fortune, partly recovered from photographs taken at Harvard College. Professor E. C. Pickering, the Director, recently conceived the idea of "patrolling the heavens," every fine night, by means of a small photographic transit instrument, which automatically sweeps the meridian in a series of steps of sufficient exposure to photograph 6th-magnitude stars, at intervals corresponding to the equatorial breadth of the field. The scheme is perfectly adapted for the detection of strange objects brighter than the 6th magnitude, and its merits were thus clearly demonstrated within a few months of its inception. The *Nova* was found on thirteen photographs taken on December 10, 11, 13, 17, 18, 18, 28, 30, January 5, 8, 9, 16, 20. It does not appear on a photograph taken at Heidelberg on December 8, showing stars to the 9th magnitude.

After remaining of the 4th or 5th magnitude till the end of

February, the *Nova* diminished somewhat rapidly in brightness, and by the end of March was of the 12th to 14th magnitude. Photometric observations were made by many observers, and both visually and photographically; and the comparison of the different series should give valuable results, especially the study of the discrepancies between photographic and visual magnitudes with special reference to the changes in the spectrum mentioned, below. No detailed comparison has, however, yet been made. The star was followed visually at the Lick Observatory until April 26, when a three weeks' storm interrupted observation. Its magnitude is then given as 16·2.

After thus practically disappearing, the *Nova* was found to be again easily visible in August. At the Lick Observatory it was found to be of magnitude 10·5 on August 17, and 9·8 on August 19. The brightening was detected independently in England by Mr. H. Corder about the same time, but the first published observation is that of Mr. Espin (to whom Mr. Corder had written), on August 21. The star is now of about magnitude 12, and fluctuations in brightness have occurred, which indicate that it must be carefully watched in the future.

*The Spectrum and Spectroscopic History of Nova Aurigæ.*

It was to be expected that no pains would be spared to make the spectroscopic study of the *Nova* of 1892 as complete as possible. Its spectrum was the first consideration at every observatory, and from all the observers came the same notice of a brilliant array of bright broad lines.

It soon became clear that the bright lines were not the only features of the spectrum: it was simultaneously noted at Tulse Hill, South Kensington, and Stonyhurst, and first announced by Professor Lockyer, that the bright lines were attended by dark companions on the more refrangible sides. Numerous finer details were then added to the spectrum, dark lines crossing the broad bright bands, and bright lines marking the dark companions; and it was found that there were changes in progress amongst these more delicate parts of the spectrum. A careful watch was kept upon the stronger lines to note any changes in them, whether of their position or width; but up to the last appearance of the lines, in the waning light of the star, they showed the same broad front.

The analysis of the spectrum has been conducted with great care at many observatories by comparisons with terrestrial radiations, with the spectra of other stars, and with carefully-constructed wave-length charts for the instruments employed. There is a want of accord between the results from the several observatories, which is in part, no doubt, due to the great width of the lines under observation; but the collective evidence upon the details of the spectrum has yet to be studied, and this is hardly

possible without a very full description of each line and of the instrument in use.

Three of the lines, however, have attracted more attention everywhere on account of their intimate connection with the suspected physical constitution of the star. These are (1) the bright-green line near $b_4$, and the less refrangible edge of the hydrocarbon band; (2) the line near to the chief nebular line $\lambda$ 5006; and (3) the line near to the pair of chromospheric lines $\lambda$ 4923 and $\lambda$ 4921. When the wave-lengths of these lines, as quoted by the observers, are corrected for motion in the line of sight, and arranged in a table, the mean values come out very closely as the wave-lengths of three notable pairs of solar chromospheric lines; while magnesium and the hydrocarbons, as possible origins of line (1), are excluded by the absence from the lists of their inseparable companion-lines and flutings.

Line (2) is claimed by four observers for the chief nebular line, the mean of their measures being 5005; but the majority is a very strong one against it, the mean of eight measures being 5015, and Huggins, Vogel, and Young, who have made a special study of this line, have pronounced emphatically against its nebular origin, independently of the absence of its mate at $\lambda$ 4957.

Thus, by the successive exclusion of previously suspected origins, the outburst of light in the *Nova* came to be recognised as a vast chromospheric disturbance; a view confirmed by Dr. Huggins's discovery, on February 22, of the complete series of bright hydrogen lines in the ultra-violet—the same that Hale and Deslandres discovered in the solar chromosphere,—but each with its dark companion.

In studying the character of individual lines it was necessary to determine whether the wideness should be attributed to a single or to a multiple origin. The two strong hydrogen lines at F and G′ were certainly divided by a faint dark line near the centre of each; and the two parts might belong to separate sources of hydrogen, or to hydrogen and some other incandescent gas. The separation, centre from centre, of the broad bright line and its dark companion at F already showed an enormous relative velocity of the origins; it could not be less than 500 miles in the second. The subdivision of the lines into separate hydrogen flames would introduce a much greater velocity. Dr. Huggins, however, drew attention to the similar double, and in some cases triple, reversals obtained in the laboratory by Professor Liveing and Dewar as furnishing a more probable explanation of the apparent subdivisions. This has been accepted as probably the true account of most of the finer details of the spectrum; and the supposition has been greatly confirmed by the solar photographs at Paris, Chicago, and Stonyhurst, which show these reversals on the bright faculæ which belong to the solar chromosphere. There remained, however, some uncertainty about the position, in the broad line, of the origin of the widen-

ing; for in the laboratory the widened lines were not always found with equal parts on both sides of the true line. But the true position was always marked by a maximum intensification; and Professor Vogel found a like position in the hydrogen F of the *Nova*. Measuring, therefore, from this centre, the Potsdam line-of-sight spectrograph gives, with reference to the earth, a receding velocity of 230 miles to the bright hydrogen, and an approaching velocity of 320 miles in the second to the origin of the dark lines.

The difficulty of accounting for these extraordinary velocities has been felt by all astronomers. A single star at such a speed would only mean the addition of one to our small list of known high-speed wanderers; but two in the same line of sight, and maintaining their velocities unchanged for seven weeks, postulates either an all but inadmissible chance meeting, or a system under the control of a distant mass too great to leave the universe of stars at apparent rest.

It is not possible here to do more than to refer the reader to the authors of the several explanations offered during the year. The meteoritic theory by Professor Lockyer is outlined in the *Nineteenth Century*, vol. xxxi. The chromospheric theory of the near approach of two stars is given by Dr. Huggins in the June number of the *Fortnightly Review*; Seeliger's modification of the meteoritic theory is translated in *Astrophysics* for December from *A.N.* 3118; and a single-star chromospheric theory is offered by the Rev. W. Sidgreaves in the October number of the *Observatory*.

The revival of the star in August has added to its mysteries. The new spectrum is claimed by Professor Campbell and by Herr E. von Gothard to be that of a planetary nebula with a displacement towards the blue of five tenth-metres. Its light is, however, too feeble for the measures of the wave-lengths of the lines observed to be implicitly accepted, and it is premature to discuss the question until time shall have shown whether the star be merely a "temporary" one, or one with a variation between the tenth and seventeenth magnitudes. W. S.

*Variable Stars. Discovered at the Harvard College Observatory during the year* 1892, *by Mrs. Fleming, in the regular examination of stellar spectra.*

| Constell. | R.A. h m | Dec. ° ′ | Gr. Br. | Lt. Br. | Description. |
|---|---|---|---|---|---|
| Horologium | 2 49·7 | −50 21 | 6 2 | 9·7 | Type III., hydrogen lines bright |
| Octans | 5 56·8 | −86 26 | 7·4 | < 11·3 | ,, ,, |
| Boötes | 14 22·3 | + 5 7 | 8·2 | 10·7 | ,, ,, |
| Libra | 15 18·5 | −22 34 | 8·4 | < 11·0 | ,, ,, |
| Scorpius | 16 56·8 | −36 46 | 8 | < 11 | ,, ,, |
| Octans | 17 25·9 | −86 46 | 8·2 | < 11·7 | ,, ,, |
| Sagittarius | 19 49·8 | −29 27 | 7·5 | < 12·6 | ,, ,, |
| Tucana | 23 52·2 | −65 56 | 10·2 | < 12·6 | ,, ,, |

The sixth star in the above list is A.G.C. 27271 Mag. $8\frac{1}{2}$.

The letters A.G.C. in the above lists are used to indicate the Argentine General Catalogue.

These stars were all discovered from the presence of bright hydrogen lines in their photographic spectra. No stars are included of the variability of which there is any doubt, and in every case the change exceeds two magnitudes.

*New Double Stars, discovered in* 1892, *and measures.*

[*The following are all due to Mr. S. W. Burnham.*]

| β | Star. | R.A. h m s | Decl. ° ″ | P ° | D ″ | M | 1800+ | |
|---|---|---|---|---|---|---|---|---|
| 1267 | ... | 5 27 22 | +30 51 | 217·9 | 0·84 | 8·5... 8·5 | 92·13 | ... |
| 1268 | 24 Musc. | 7 9 11 | + 0 3 | 313·2 | 3·81 | 6 ...11·8 | 92·21 | ... |
| 1269 | 44 Hydræ | 10 28 18 | −23 8 | 63·8 | 18·33 | 5 ...14 | 92·23 | ... |
| 1270 | LL. 25825 | 13 57 46 | + 9 14 | 329·7 | 0·27 | 8·2... 8·3 | 92·27 | ... |
| 1271 | Rad. 3181 | 14 13 4 | +55 6 | 355·2 | 2·81 | 6·8...12·0 | 92·36 | ... |
| 1272 | ... | 14 13 21 | +49 18 | 132·5 | 1·25 | 8·4... 9·5 | 92·17 | A B |
| ... | ... | ... | ... | 321·8 | 23·67 | ... 8 6 | 92·17 | A C = H 2710 |
| 1273 | ... | 14 14 2 | +48 28 | 193·0 | 1·08 | 8·6... 9·8 | 92·17 | ... |
| 1274 | B.A.C. 6216 | 18 12 35 | +56 33 | 147·1 | 0·88 | 9·8...10·6 | 92·37 | B and C |
| ... | ... | ... | ... | 8·5 | 5·03 | ...10·4 | 92·37 | B and D |
| ... | ... | ... | ... | 239·1 | 95·61 | 6·4... | 92·35 | A and B |

*New Nebulæ discovered by Lewis Swift at Warner Observatory, Rochester, New York.*

| 1892. | R.A. h m s | Decl. ° ″ | | |
|---|---|---|---|---|
| Mar. 28 | 9 35 50 | +12 56·0 | *ee*F, *es*, almost stellar | |
| Apr. 16 | 10 55 35 | +11 3·2 | *ee*F, *vs*, *ee* diff. N.G.C. 3492 near. | 4th of 4 |
| 18 | 11 22 30 | +59 9·2 | *vs*, close D with 3690 = H 247·1 suspected with 132, ver. with 200. | |
| May 16 | 14 14 12 | − 3 58·4 | *p*F.S.R. star with distant companion near *n*. | *p* of 2 |
| 16 | 14 14 30 | − 3 57·4 | *ee*F.S.R. *e* diff. | *f* of 2 |
| 17 | 14 34 50 | + 3 50·0 | *e*F, *vs*, little elongated. | 1st of 3 |
| 17 | 14 35 4 | + 3 56·0 | *ee*F.S.R. close D with 5718. | 2nd of 3 |
| June 16 | 15 52 50 | +12 23·8 | *ee*F, *ps*, R. in centre of rhombus of 4 stars, *v* diff. | |

*Stars having Peculiar Spectra. Discovered at the Harvard College Observatory during the year 1892, by Mrs. Fleming, in the regular examination of stellar spectra.*

| Designation. | R.A. 1900. h m | Dec. ° ′ | Mag. | Description. |
|---|---|---|---|---|
| B.D. +53° 379 | 1 38·8 | +53 28 | 9·4 | Type IV. |
| A.G.C. 9326 | 7 14·8 | −36 33 | 5·3 | F line bright |
| A.G.C. 10963 | 8 9·7 | −35 35 | 5·3 | ,, |
| ... | 10 7·6 | −60 8 | ... | Type V. |
| ... | 10 13·3 | −57 24 | ... | ,, |
| A.G.C. 14691 | 10 40·3 | −59 12 | 8½ | ,, |
| ... | 10 43·4 | −58 41 | ... | ,, |
| ... | 10 47·3 | −61 46 | ... | ,, |
| A.G.C. 14971 | 10 52·2 | −59 55 | 7¾ | ,, |
| ... | 10 55·8 | −57 17 | ... | ,, |
| ... | 11 55·2 | −54 33 | ... | ,, |
| ... | 13 24·3 | −61 34 | ... | ,, |
| *A.G.C. 20937 | 15 21·9 | −24 49 | 6¼ | Peculiar |
| ... | 15 55·0 | −62 28 | ... | Type V. |
| B.D. +9° 4369 | 19 56·3 | + 9 14 | 8·7 | Type IV. |
| *Discovered by Mr. A. E. Douglass, at Arequipa, Peru.* | | | | |
| A.G.C. 16710 | 12 9·1 | −50 45 | 8½ | Type IV. |
| A.G.C. 19254 | 14 7·4 | −53 28 | 7·5 | Type IV. |

The spectrum of this star resembles that of the well-known gaseous nebula surrounding 30 *Doradus*, which is unlike that of ordinary gaseous nebulæ.

### *The Direction of the Solar Motion.*

The most important addition to the literature of this subject, during the year, has been contributed by Professor J. G. Porter, of Cincinnati, who has availed himself of the proper motions given in the Catalogue of 1340 stars, published in number 12 of the Transactions of that Observatory. The author has followed the method indicated by Dr. Schönfeld in the V. J. S. xvii. p. 256, without any important alterations. He has divided his stars into four groups, according to the amount of the annual proper motion, and thus has four distinct determinations based upon the following data:—

| | | | |
|---|---|---|---|
| Group I. | 576 stars | proper motion less than | 0″·3 |
| ,, II. | 563 ,, | ,, | between 0″·3 and 0″·6 |
| ,, III. | 142 ,, | ,, | between 0″·6 and 1″·2 |
| ,, IV. | 70 ,, | ,, | greater than 1″·2 |

The complete solution of the equations of condition should exhibit the change of the galactocentric longitude of a star, measured in the plane of the Milky Way, but as in the case of Dr. Stumpe's investigation, the author has found it advisable to make this term equal to zero.

Rejecting this term, the co-ordinates of the apex of the Sun's way are derived separately from the proper motions in R.A. and Dec., and although the disagreement in the results is in some cases very noticeable, yet the directions derived from the two, when combined by means of the weights which Professor Porter has determined, are in fair mutual agreement in the whole four groups and accord with the results of previous researches.

The following positions are assigned to the apex of the Sun's way :—

| | Right Ascension. | Declination. | Annual Motion. |
|---|---|---|---|
| | ° | ° | ″ |
| Group I. | 281·9 | +53·7 | 0·16 |
| „ II. | 280·7 | +40·1 | 0·30 |
| „ III. | 285·2 | +34·0 | 0·55 |
| „ IV. | 277·0 | +34·9 | 1·66 |

These results generally confirm those derived by Dr. Stumpe, which will be found in the *Monthly Notices*, vol. li. p. 246, and where the " Annual Motion " has the same significance as in this case.

Professor Vogel has also published the results of a very interesting inquiry on this subject, based on the measured velocities of stars in the line of sight. The motion of fifty-one stars has been determined at Potsdam, and since the probable error in the measurements is below 1·16 geographical miles, the data seem sufficient for a determination, not only for the velocity of the solar motion, for which the observations are particularly well adapted, but also for the position of the apex of motion. The inquiry has been effected by Dr. Kempf by two different methods, but the resulting position of the apex is in neither case in very satisfactory accord with other investigations, indicating probably that the inquiry is premature, and based upon an insufficient number of stars. If the stellar motions be treated either with equal weights, or weights approximately proportional to those assigned by Dr. Vogel in his catalogue of proper motions, the co-ordinates of the apex are as follows :—

$\alpha$ . . . $206^\circ 1 \pm 12^\circ 0$

$\delta$ . . . $+45^\circ 9 \pm 9^\circ 2$

Velocity . . . 11·60 ± 1·85 geographical miles.

If, however, the neighbouring stars, such as the bright stars of *Ursa Major* and of *Orion*, be combined into groups, the position of the apex is still further from that generally assigned, viz. :—

$\alpha$ . . . $159°.7 \pm 20°.2$

$\delta$ . . . $+50°.0 \pm 14°.3$

Velocity . . . . 8·11 ± 2·04 geographical miles.

If, again, the position of the apex as given by L. Struve ($\alpha = 266°.7$, $\delta = +31°.0$) be assumed, and only the velocity of the solar motion be derived, this value becomes $7·69 \pm 1·85$ geogr. miles. W. E. P.

*Solar Activity in* 1892.

Though the point of maximum solar activity has probably not yet been reached, the increase in every kind of solar phenomenon has been so rapid during the two past years that already the numbers recorded during the maximum of 1882–4 have been equalled, and in some points surpassed.

To begin with, there have been no days on which the Sun has been free from spots in 1892, as against three in 1882, and eight in 1883. Then the great group of 1882 November, the largest of the past cycle, only attained an area of 2,425 millionths of the Sun's visible hemisphere, as measured on the Greenwich photographs, whilst the group of February last, at its greatest extent, covered 3,528 millionths. So far, too, as the records of the year are as yet available, it would appear that the mean daily spotted area was fully as large as for 1883, the most prolific year of the last maximum.

The most remarkable group of spots of the year was, of course, that of February, but the last ten days of April, the month of July, and the early part of October were also especially distinguished by the number and size of the groups then seen upon the disc.

The reports of Professor Tacchini show that the prominences have taken part in this revival, the mean daily number observed being greater by one-third than in 1891, and the mean extent of each has increased in about the same proportion. Several individual outbursts of extraordinary violence have also been recorded. Of these, two were associated with the great sun-spot of February, one of the two, the prominence seen by M. Fényi on February 19, attaining a height of more than 2′ of arc, and being of the most remarkable brightness. Another prominence watched by the same observer on May 5, rose rapidly from the limb of the Sun, and at its greatest elevation attained a height of more than 9′. M. Trouvelot also has recorded some striking instances of prominences of unusual size or speed of motion.

The distribution of the spots in solar latitude furnishes a useful indication of the progress which the cycle has made; and during the past year the great majority of spots have been included in the two zones 10°–30°, with a growing tendency on

both sides of the equator towards the lower half of the zone. As yet, however, the mean distance of all spots from the equator is not nearly so low as 13°, the position recorded in 1883. Both spots and faculæ have, according to MM. Marchand and Guillaume, been distributed nearly equally between the two hemispheres, the northern hemisphere having a slight advantage. This circumstance also, if the precedents of the last cycle be followed in this, would show that the maximum still lies before us.

### *Prominence Photography.*

The suggestion of M. Deslandres, noted in the report of the Council last February, that it might be possible to photograph the entire chromosphere at a single exposure, has been carried into actual effect during the past year by Professor G. E. Hale. The instrument Professor Hale has devised for the purpose, and which he has entitled the "spectroheliograph," possesses as its essential feature an arrangement driven by a clepsydra, by which the slit of the spectroscope is made to travel across the image of the Sun, and a precisely similar motion, but in an opposite direction, is given to a second slit nearly in the focus of the view telescope, and so arranged that the K line of the spectrum of the fourth order falls upon it. Since the K line is always bright in the spectrum of the chromosphere and prominences, it is easy, by shutting off the image of the Sun by means of a diaphragm, to build up a complete picture of the entire chromosphere and prominences, and so to produce what may be described as an "artificial total solar eclipse."

The discovery which Professor Hale has made that the H and K lines are always reversed in the faculæ has enabled him to extend the application of this principle. If the diaphragm, covering the image of the Sun, be discarded, a photograph will be obtained, not merely of the chromosphere and prominences, but of the disc of the Sun itself, showing the spots and the faculæ, the latter being depicted not merely when near the limb of the Sun, but wherever they occur, even in the very centre of the disc. In this manner it has been discovered that faculæ invisible to the eye frequently float above the spots, and one series of photographs in particular, copies of which have been presented to the Society by Professor Hale, show how, on July 15, a luminous outburst formed, spread, completely hid a large group of spots, and passed away, all in a few minutes of time.

The *double* reversal of the H and K lines from faculæ, a phenomenon shown upon photographs taken at Kenwood, Paris, and Stonyhurst, is a discovery of special interest as bearing upon the interpretation of the enigmatical spectrum of *Nova Aurigæ*, and Professor Hale has supplemented this discovery by obtaining a similar result with an integrating spectroscope, the Sun being

treated as a star would be, its light as a whole, and not only from special regions of the disc, being subjected to examination.

M. Deslandres, with a spectroscope from which glass had been excluded, has continued his researches on the ultra-violet spectrum of prominences, and has succeeded in securing as bright lines in the spectrum of a specially brilliant prominence not only the entire series of hydrogen lines photographed by Dr. Huggins in the spectra of stars of the *Sirius* type, but also five other lines which, from their conformity to Balmer and Ames's formula, may be concluded to belong to the same element. The same prominence yielded also lines due to aluminium, iron, and magnesium, besides many others the sources of which have not yet been determined.

M. Deslandres is also at work upon a yet more interesting research, the photographing the corona apart from an eclipse. The principle upon which he proceeds is to obtain photographs of the Sun from light of limited refrangibility, not by using coloured media or stained plates, but by means of two prisms, the second of which is arranged so as to recompose the light dispersed by the first. But only certain rays from the first prism are allowed to fall on the second; the resulting image of the Sun is therefore confined to these rays, which can be selected at pleasure. M. Deslandres's purpose is therefore to find out for what rays the corona has the greatest brightness as compared with that of the Sun, and to photograph the Sun and its surroundings by their aid alone. Some of his experiments have already given him images with a distinctly coronal appearance, but he withholds an expression of opinion as to their reality until an opportunity occurs of comparing them with photographs taken simultaneously during a total solar eclipse or by a similar process at distant and elevated observatories.

### *Lunar Theory.*

M. Radau has published during the year 1892 some important work on the inequalities of long period, suggested by the researches of Mr. G. W. Hill. He has succeeded in simplifying the computation of the inequalities due to planetary action, firstly by decomposing the disturbing function into a series of groups, and next by introducing systematically the expressions—

$$\Delta b_s^i = b_s^i - \alpha b_s^{i-1}, \qquad \Delta^2 b_s^i = b_s^i - 2\alpha b_s^{i-1} + \alpha^2 b_s^{i-2}, \text{ \&c.},$$

where $b_s^i$ is a Laplace's coefficient. M. Radau has tabulated a list of arguments of long period which might be important, and has examined a large number of them, some of them giving rise to inequalities of several tenths of a second in amplitude. He has also shown that the arguments $(2w - 3y)$ and $(2w - 5\,\mathrm{L}' + 3\,\mathrm{V})$, due to the action of *Jupiter* and *Venus* respec-

tively, each produce an inequality of long period, together with a sensible inequality of short period, just as in the case of the argument $(2w-2y)$ considered by Mr. Neison and Mr. Hill. Thus there are several inequalities to be taken into account in comparing Hansen's tables with observation.

### *Selenographical Notes.*

The critical examination of the fine negatives of the Moon taken during the last two or three years with the 36-inch refractor of the Lick Observatory has tended to give a very decided impulse to selenography. Some of the more perfect examples of these productions have been submitted to Dr. L. Weinek, of Prague, who, with a great expenditure of skill and patience, has succeeded in producing enlargements of certain formations included in these photographs which have brought to light many unrecorded features. Beautiful photogravures of his faithful delineations of some of these enlargements have recently been published in a volume dealing with the astronomical observations made at the Royal Observatory at Prague during the years 1888–91, among which perhaps the most remarkable are those representing the great walled plains, Petavius and Vendelinus.

During the past year Prof. W. H. Pickering, at Arequipa, has devoted much attention to the observation of lunar detail with the large telescope in his charge. His observations relate mainly to the craterlets and minute light spots on the floor of Plato, and the bright streaks radiating from Tycho, Copernicus, and other formations. His Plato investigations go far to strengthen the suspicion that changes in the appearance and visibility of the spots have taken place during the last twenty years. As regards the bright streak systems, he contends that the various rays of which they are composed are not so long or continuous as has been hitherto believed, but that they rarely exceed fifty miles in length, and are often not more than ten miles long; while at the minute craters from which, as he maintains, they issue, they are not more than a quarter of a mile in width. He suggests that they may be due to the deposition of fine white dust or powder ejected from certain small craters that lie in the path of the rays, which is carried by wind currents caused by the condensation and absorption in surrounding regions of large quantities of gas or steam emanating from craters near the ray centres. His ingenious hypothesis appears to resemble in many respects that advanced many years ago by M. Chacornac.

During the past year certain craters and other details have been detected which are not recorded in Schmidt's large map of the Moon, many of them being visible in instruments of very moderate size under suitable conditions. Some of these objects were found on enlargements of the Lick Observatory negatives, and their existence subsequently confirmed by direct observation.

The discovery of others is mainly due to the systematic scrutiny of certain formations (Vendelinus, Ptolemaus, the surrounding region, &c.) by the Lunar Section of the British Astronomical Association. T. G. E.

### *M. Trouvelot's Observations of Venus.*

An extensive and important series of observations of the planet *Venus* by M. Trouvelot has recently been published by the Société Astronomique de France. The observations appear to have been very carefully made and are very numerous, as many as 744 observations and 295 sketches of the planet having been obtained since the year 1876. The memoir is divided into 10 sections, the first of which relates to the visibility of *Venus* to the naked eye in full day. The planet is said to be thus visible in all parts of its orbit in the clear sky of Cambridge, U.S.A., when its angular distance from the Sun is not less than 10° near inferior, or 5° near superior conjunction.

Section III. deals with certain whitish and greyish spots. These nearly always appear in the neighbourhood of the terminator, and are generally of short duration. But a grey spot of a different character to the others was observed in 1876. It was characterised by its large size, its long duration, and by its comparatively well-defined and peculiar form. A marking of almost identical appearance was also frequently observed in 1891, and the author is inclined to believe that these two spots were really one, and that we have here a permanent spot usually concealed by an ordinarily opaque atmosphere, and only becoming visible when there is a temporary clearance in the atmospheric layers situated above it. A large number of observations of the spot of 1891 are given at length, and these indicate a curious circumstance. The spot appears to have arrived at the same position on the disc at a later and later time on each succeeding day. The author concludes that this peculiarity indicates a period of rotation slightly longer than that of the Earth.

Section V. is on the polar spots of *Venus*. These consist of brilliant white spots of a permanent nature, nearly always visible on the limb near the two horns, and never departing much from these positions. From their nearly invariable position the author considers that these spots mark the poles of rotation of the planet, and that they really consist of high mountain masses emerging beyond the dense atmosphere of the planet. Under favourable circumstances the margins of these polar spots have appeared formed of minute brilliant points or separate peaks. M. Trouvelot points out that these polar spots have been seen in some form or other by a large number of observers. From their positions, as given in a great many drawings, and from measures of their angle of position, he concludes that the equator of the planet is only inclined 10° or 12° to the plane of the orbit of *Venus*, and that the north polar spot is at a summer solstice

when the longitude of the planet is 92°. These elements differ largely from those generally stated, and it will be noticed that the old conclusions of Schroeter as to the existence of lofty mountains are revived in the present memoir. In fact, many of the phenomena noted by Schroeter are confirmed by the present series of observations.

The two succeeding sections deal with the terminator, horns, and phase. A great many observations and sketches are given, and it appears that the line of the terminator often departs from a regular curve, and that the horns undergo considerable variations. From observations of 9 elongations dichotomy occurred at east elongation 4 to 8 days before, and at west elongation 6 to 11 days after, the time of greatest elongation.

The question of the duration of the rotation of *Venus* is, perhaps, the one of most importance just at present. M. Trouvelot examines this question at some length, especially in connection with the observations of Professor Schiaparelli, and concludes that the motion of rotation is a rather rapid one, not differing much from 24 hours. A. S. W.

### *The Opposition of Mars.*

The recent opposition of *Mars*, though one of the first order as regards the proximity of the planet, has not added much to our knowledge of its surface and physical condition. This has been partly due to the prevalence of bad observing weather near the time of opposition, but still more to the great southern declination of the planet, which rendered it very difficult for northern astronomers to observe with advantage.

The principal observations recorded are the following: The rapid decrease of the white cap round the south pole during the interval from the spring equinox to the summer solstice of the planet's Southern Hemisphere; the detection by M. Perrotin, and independently by Professor W. H. Pickering and other observers, of a number of bright white spots, other than the polar caps, and which appeared, when close to the limb, to project beyond it; the identification by several observers of some of Schiaparelli's "canals," the detection of some new ones, and the observation of the duplication of two or three—in one case, that of the *Ganges*, the phenomenon being independently recorded by several widely-separated observers; the suggestion of the discontinuity of the "canals," by Professor Young, apparently confirmed in one instance by a drawing by Mr. Walter Gale; and, lastly, the establishment of the fact that considerable changes have taken place in various regions of the planet, and more especially in the neighbourhood of Green's Terby Sea, the *Lacus Solis* of Schiaparelli's nomenclature. The published drawings, of which a large number have appeared in *L'Astronomie* and *Astronomy and Astro-Physics*, appear to emphasise three facts: (1) The stability of certain leading features

of the planet; (2) The great extent to which personal differences affect designs of this planet, perhaps the most difficult object in the heavens to sketch truthfully and satisfactorily; and (3) the occurrence of real changes in the appearance of the planet on a scale which it is difficult to reconcile with the usually accepted theory that the brighter and darker markings indicate respectively land and sea.

On this point Mr. Schæberle has argued that the ordinary interpretation should be reversed and that the brighter markings represent water. To this contention he will receive little assent. Professor W. H. Pickering, whose position at the lofty station of Arequipa, where *Mars* was nearly in the zenith, gave him special facilities for observation, regards only the very darkest of the dark regions as sea, and confines the water on the planet to the Kaiser Sea and Herschel Strait. Professor Pickering has also given great attention to the colour of the different districts of the planet, and has made several interesting observations in this direction. These claim a delicate discrimination of tint considerably in advance of anything previously secured, and, though observations made in a field where personality is so influential as colour perception must be received with some reserve until independently confirmed, the advantages Professor Pickering has enjoyed for this research are very great.

### *The Orbit of Iapetus and Mass of Saturn.*

The mass of *Saturn*, deduced by Professor A. Hall from observations of *Iapetus*, made during the years 1875, 1876, and 1877, with the great Washington refractor, was $\frac{1}{3481}$, whilst that deduced by Mr. A. Hall, junr., from heliometer measures of *Titan* made at Yale in 1885–87 was $\frac{1}{3501}$, agreeing substantially with the results obtained by Bessel and H. Struve.

Under these circumstances Professor A. Hall undertook a fresh series of observations of *Iapetus* in 1889 and 1890, the results of which are published in the *Astronomical Journal*, No. 253. In 1889 the orbit plane of *Iapetus* had returned to a similar position to that which it occupied in 1875, except that the apparent motion of the satellite was reversed, and Professor Hall consequently followed his plan of 1875–77 in observing differences of right ascension and declination of *Saturn* and *Iapetus*; the determination of the mean distance of the satellite depending almost entirely on the former, as the differences of declination were very small.

Professor Hall decided to include all the observations obtained in his final solution of the equations, although there appeared to be a systematic difference between the measures

made with the filar micrometer and those obtained by means of the chronograph, which sensibly increase the probable errors of his results. The corrections to the previously-obtained values of the mean longitude and period are small, indicating that the assumed values are nearly correct, whilst the position of the perisaturnium is still somewhat uncertain. The correction to the assumed value of the mean distance, 515″·5195, is − 0″·2153 ± 0″·06387, and the corresponding value of the mass of *Saturn* is $\frac{1}{3485{\cdot}7 \pm 1{\cdot}28}$.

A. M. W. D.

*The System of Algol.*

Argelander demonstrated the prevalence of cumulative inequalities in the period of Algol's light-change; but it was not until 1888 that their law was investigated by Dr. Chandler (*Astronomical Journal*, Nos. 165–7). Through the discussion of nearly 700 observed minima, he succeeded in resolving the inequalities they attested into two principal components—one with a period of about 141 years, and a coefficient of 173·3 minutes, the other with a period of 37·7 years, and a coefficient of eighteen minutes, upon which a third small variation in seventeen years appeared to be superposed. Early in the past year, he propounded a theory of a highly interesting character explanatory of the main part of these inequalities. They cannot be the immediate product of gravitational action, the distance implied by the length of period precluding the possibility of connecting effects so considerable with the presence of a perturbing body. They are accordingly ascribed to differences in the times of light-transmission from the various parts of a large orbit described by *Algol* and its close companion round an invisible primary. This orbit is sensibly circular, and lies in a plane inclined about 20° to our line of sight. It is traversed in 131 years, at a distance from the centre of gravity of the system of nineteen astronomical units, or just that of *Uranus* from the Sun, and light crosses its foreshortened radius in 149 minutes. To this extent, then, the eclipses of *Algol* seem alternately accelerated and delayed, as the star approaches towards, and retires from, the Earth. A retardation, amounting in 1843 to 165 minutes, shows, however, that the theory does not completely cover the facts, and Dr. Chandler fully admits the concurrence of further disturbances, the explanation of which will demand prolonged researches. Its fundamental assumptions are, indeed, capable of easy verification. The star is timed to reach the nearest point of its orbit to ourselves within six or seven years, when a maximum of acceleration should occur, after which the intervals between each eclipse should begin steadily to lengthen, until, at the passage of the ascending node, about 1934, coincidence of their observed and mean epochs should come to pass, to be again followed by a lagging of the

former. The velocity of *Algol* in its hypothetical wide orbit is two and a half miles a second, of which less than half is at present directed towards the Earth.

Dr. Chandler's inferences do not rest wholly upon fluctuations in this star's period of variability. He derives confirmation to his theory from meridian observations of it since 1753. They seem to show an undulatory mode of progression, due possibly, as he supposes, to the description of a projected ellipse with a major axis of $2''{\cdot}7$. It is, nevertheless, far too soon to pronounce upon the true character of deviations from rectilinear motion, which, although they appear to proceed regularly, both in right ascension and declination, may turn out to be purely accidental. Their reality is, however, countenanced by the identity of the parallax which they imply for *Algol* of $0''{\cdot}07$, corresponding to a light-journey of nearly forty-seven years, with that photographically determined by Professor Pritchard. The emissive power of a star so curiously associated with two obscure masses would, at that distance, be equal to that of *Sirius*. Dr. Chandler does not despair of the actual telescopic discovery of the primary body, if even slightly luminous. Its position-angle relative to *Algol* is just now 32°; its distance, assuming the correctness of Vogel's elements for the close couple, should be $2''$. But even if it have an objective existence, it may be doubted whether it will ever be seen. A. M. C.

*Sirius and its Companion.*

The Companion of *Sirius*, having traversed nearly 90° of its relative orbit since its optical discovery by Alvan Clark in 1862, has now approached its primary so closely that it will be impossible to obtain any measures of its position for at least two or three years from the present time. Professor Auwers has accordingly taken this opportunity to continue his researches on the motions of the *Sirius* system, and has published his results in *Astronomische Nachrichten*, Nos. 3084–85.

Starting from the elements of the orbit of *Sirius* with respect to the centre of gravity of the system, deduced from meridian observations which he published many years ago in *Publicationen der Astronomischen Gesellschaft*, No. vii., Professor Auwers has compared the measures of the relative position of the Companion, made since its discovery, with an ephemeris computed from the above-mentioned elements on the assumption that the ratio of the mass of *Sirius* to that of its Companion is $2{\cdot}05 : 1$, and, therefore, that the mean distance in the relative orbit is $a\,(1+2{\cdot}05) = 7''{\cdot}109$; $a$ being the mean distance in the orbit described by *Sirius* relative to the centre of gravity. From the residuals thus obtained Professor Auwers computes corrections to the assumed elements, with the exception of the period which of course cannot be satisfactorily determined from observations

extending over 90° of anomaly only. From a comparison of the individual observations with the places computed from the resulting elements Professor Auwers determines the "personal equations" of the several observers who took part in the measures, and, introducing the values thus obtained into the equations of condition, proceeds to a second approximation. The elements determined (1) from meridian observations of *Sirius* (with the above-mentioned assumption as to the ratio of the masses), and (2) from measures of the relative position-angle and distance of the Companion with respect to *Sirius* are as follows:—

| | (1.) | (2.) |
|---|---|---|
| T | 1843·275 | 1844·216 |
| U | 49·399 years | 49·399 years |
| $n$ | −7°·2877 | −7·2877 |
| $a(1+m)$ | 7″·109 | 7″·568 |
| $e$ | 0·6148 | 0·6292 |
| $i$ | 47° 8′·7 | 42° 25′·6 |
| $\Omega$ | 61° 57′·8 (1850) | 37° 30′·7 (1850) |
| $\pi-\Omega$ | 18° 54′·5 | 39° 56′·5 |

A comparison of the meridian observations of *Sirius* from which the elements (1) were obtained (extending from 1750 to 1864), with places computed from the elements (2), but with the original value of $a$—*i.e.* 2″·3307—gives for correction to $a$ from observations of right ascension +0″·2708, and from observations of declination −0″·2958. Adopting a weighted mean correction +0″·0910, the corresponding value of $a$ is 2″·4217, and, adopting the value of $a(1+m)$ from orbit (2), the corresponding ratio of the masses is 2·125 : 1. Assuming Gill and Elkin's value of the parallax of *Sirius*, 0″·38, it follows that

Mass of bright star = 2·21 × mass of Sun.
Mass of companion = 1·04 × mass of Sun.

Professor Auwers includes two useful ephemerides in his paper, one giving the relative position-angle and distance of the Companion referred to the Primary Star, and the other giving the differences of right ascension and declination of the bright star referred to the centre of gravity of the system. The researches embodied in this paper place beyond reasonable doubt the identity of the Alvan Clark Companion with the body which causes the observed irregularities in the motion (transverse to the line of sight) of the bright star; and, notwithstanding the uncertainty in the value of $a$, arising from discordance in the results deduced from the right ascensions and from the declinations, supply us with the means of computing the relative positions of the components of the *Sirius* system with (in all probability) considerable accuracy for, at least, several years to come. A. M. W. D.

*Measures of Rutherfurd's Star Photographs.*

On 1890 November 13, our late Associate Lewis M. Rutherfurd, presented to the Columbia College Observatory his complete set of original negatives (wet plates) of the Sun, the Moon, and many star clusters; also some thirty quarto volumes of measures of certain star plates. A catalogue of the plates was published in the *Annals of the New York Academy of Sciences*, vi., 1891 June.

Mr. Harold Jacoby, of the Columbia College Observatory, immediately set about the reduction of the star measures, beginning with the latest plates of the *Pleiades*; and two memoirs, one on the *Pleiades* group, and another on the stars about *β Cygni*, have appeared within the last year. The first memoir, of 70 pp., 8vo. contains the measures of photographs in 1872 and 1874, the *Pleiades* being selected for measurement first, "because the group offers the best opportunity for judging of the accuracy obtainable by the methods employed." The result is eminently satisfactory, as appears from comparison of the places deduced with those found by the Yale and Königsberg heliometers; and it is concluded, with good reason, that the "present photographic observations are entitled to be taken into consideration if it be desired to make a study of proper motions, or to form a definitive catalogue of the *Pleiades*." We may, perhaps, add that remeasurement of these plates now would afford valuable evidence as to the stability of a photographic film for nearly twenty years, and would be of considerable importance in view of modern photographic undertakings.

The general accuracy of the method being thus established, several precautions adopted in the first memoir have been omitted in the second, much labour and detail in printing being thereby saved. It may be explained that in making the exposures two impressions were taken on each plate. The second impression is west of the first. After it was finished the clockwork of the telescope was stopped, and the cluster allowed to move off the plate, the brighter stars leaving "trails." Shortly before the star reached the edge of the plate, the clock was again started, and the central star was allowed to impress itself once more, thus giving the orientation. For the *Pleiades* both the eastern and western impressions were always measured, and in the reductions these sets of measures have been treated as if they came from separate plates; but the results were satisfactorily accordant, and therefore, for the *β Cygni* cluster, the measures of the eastern and western impressions were not separately reduced.

The distances were referred to a glass scale, which was carefully calibrated. Convenient formulæ and tables are given in the paper for the refraction correction. The final result is a catalogue of seventy-five stars of the *Pleiades*, and forty-two of the *β Cygni* cluster.

### *Double Stars.*

This branch of astronomy is divided into three distinct sections, discovery, micrometric measures, and, finally, discussion of the observations. It rarely happens that all three sections are taken up by one man, and the retirement of such an individual leaves a serious gap. It falls within the province of the Royal Astronomical Society to call attention to the importance of continuing the micrometric work of Mr. Burnham.

Two Burnham catalogues of new doubles have appeared during the year 1892, and practically all were discovered with the 36-inch refractor while some other pair was being examined. No systematic search was made, and yet altogether Mr. Burnham's contributions now reach the number 1,274; many of which pairs have already become well known, and many more give promise of becoming interesting systems. His measures of double stars are almost entirely confined to the more difficult and most interesting binaries, and here his retirement will be most felt. A perusal of the measures of distance tends to show that the measurement of $0''.1$ was a simple matter with the large refractor.

Professor Hall has published his measures during the years 1880–1891, in continuation of the work begun 16 years since with the 26-inch Washington refractor, and they form a valuable series of measures of close doubles, and also of wider pairs to connect his work with that of other observers.

Other measures by Maw, Seabroke, Glasenapp, Russell, and Tebbutt have been recently published. T. L.

### *Potsdam Observations of Motions of Stars in the Line of Sight.*

Professor H. C. Vogel has published during the year in the seventh volume of the *Potsdam Observations*, Part I., the details of his spectrographic determination of the motions of fifty-one stars in the line of sight. Reference to this work will be found in the President's Address on presenting the Gold Medal of the Society to Professor Vogel for his astronomical work, and especially for this particular research.

### *Drawings of the Milky Way.*

During the past year the Earl of Rosse has published reproductions of the drawing of the Milky Way made with the naked eye at Birr Castle Observatory by Dr. Otto Boeddicker, during the years 1884–89. The original drawings were exhibited at the meeting of the Society in 1889 November, and a note which accompanied them (*Monthly Notices*, vol. l. p. 12) describes the methods of observation and the means taken to ensure accuracy

in delineation. Dr. Boeddicker's work may be considered almost the only detailed representation of the northern portion of the Galaxy, since most previous drawings are either slight indications of the more prominent features, or, like that of Houzeau and the much more elaborate drawing of Heis, are mainly intended to show the relative intensity of different areas. The drawing executed in 1874–76 by M. Trouvelot fairly represents the naked-eye appearance of the Milky Way, but in far less detail than Dr. Boeddicker's, in which the complexity of structure is very remarkable. It will be important to see if all the features he delineates are confirmed by other observers, but many of these details have already been observed by Gore, Backhouse, and others.

Dr. Boeddicker's drawing extends to about 10° south declination; the stars have been taken from Argelander's *Uranometria Nova*, but the projection on which they are drawn involves considerable exaggeration in the scale. The plan suggested by Mr. Marth would avoid this disadvantage.

*The Discussion of the "Draper Catalogue."*

Professor E. C. Pickering has followed the publication of the great "Draper Catalogue of Stellar Spectra" (vol. xxvii. of the *Annals of the Astronomical Observatory of Harvard College*) by a companion volume (vol. xxvii. Part I.), in which he describes at length the methods of work employed in the formation of the catalogue, together with such additional details respecting the photographs as could not be conveniently included in the former volume. This includes, therefore, not only a full description of the Bache telescope, and the mode of its employment and of the reduction of the photographs, but also a catalogue of the 3,300 plates taken with that instrument, many of which were experimental. Following this additional information, Professor Pickering discusses in the five following chapters several points arising out of the catalogue itself. The attempt made to determine the "photographic magnitudes" of the stars observed, by comparing the intensity of the photographic images for one particular wave-length—a very important novelty in the "Draper Catalogue"—gave rise to some special difficulties, since in many stars, especially those of Secchi's second type, the photographic intensity changes at the very point of the spectrum chosen as the standard wave-length. The third-type stars were measured at four or five points, since these spectra show several regions where the intensity changes suddenly. The details of these measures, and also the measures of those stars whose photographic magnitude was redetermined on account of discordances found in the original catalogue, form an important feature of the volume.

A revision of his results leads Professor Pickering to somewhat simplify the system of classification adopted in the "Draper Catalogue." Spectra E and G are grouped together,

as are also H, I, and K, the apparent differences lying probably in the intensity of the photographic image rather than in the stars themselves, so that he almost returns to Secchi's four types, still distinguishing, however, between the two classes of spectra of the solar type, of which *Arcturus* and *Capella* may be taken as examples.

A point of great importance brought out in the present volume is the predominance of first-type stars in the Milky Way. "The Milky Way," Professor Pickering concludes, "must, therefore, be described as a distinct cluster of stars to which, from its age or composition, the Sun does not belong." But stars with types of spectra which are usually regarded as very distinct from the Sirian also exhibit a most marked preference for the Galaxy, bright line stars of the Wolf-Rayet type being strictly galactic. No fewer than nineteen of these were discovered on the examination of the photographs, all being situated within the Galaxy and close to its equator. The tendency of *Novæ* to appear within the Milky Way, or at least on some of its branches, is well known. A curious fact with regard to eye-estimates of stars in the Milky Way is also noticed by Professor Pickering—viz. that the magnitudes thus determined are too faint by about 0·2 ; an effect which appears to be nearly independent of the magnitude of the star, and practically independent of its spectrum. The last chapter gives a comparison between the visual spectroscopic catalogues of Vogel and Konkoly and the "Draper Catalogue," from which it appears that stars of Pickering's types F and G in the great majority of instances gave spectra which to the eye appear of the Sirian character. As a rule, the photographs lend no support to the idea of variation of stellar spectra, except in the cases of the "spectroscopic doubles" and of certain variables. But in some instances of stars of the second type there appears to be some evidence of a change in the relative intensity of the spectrum above and below G, due to an actual spectral change, and not to the special photographic conditions.

*Mountain Observatories.*

In 1887 Mr. Boyden bequeathed a considerable sum of money to aid in the establishment of an observatory "at such an elevation as to be free, so far as is practicable, from the impediments to accurate observations which occur in the observatories now existing, owing to atmospheric influences." In 1888, observations were taken at three stations in Colorado, namely, Colorado Springs, Seven Lakes, and Pike's Peak, and at the first-named locality the shortest wave-length yet photographed in any celestial spectrum was obtained. The experiments also showed that, after a certain height, increase of altitude ceases to be of advantage, and a more important factor is the dryness of the atmosphere.

In 1889 and 1890, experimental observations were made in

Peru, and it was decided to erect the observatory at Arequipa, at an elevation of 8,055 feet. The latitude and longitude are, roughly, 16°·24′ S. and $4^h\ 45^m\ 30^s$ W. of Greenwich. The meteorological conditions are exceptionally good; the atmosphere is very dry and clear, except during the months of November, January, and February, when the rainfall amounts to 2 or 3 inches. Throughout the year the variation of the barometer does not exceed 0·2 inches. Earthquakes are frequent and sometimes severe, and to minimise their evil effects the pier of the telescope is buried deep in solid stone masonry, and the dome is made of as light materials as possible. The instruments in use are: a 5-inch visual telescope, intended for solar work; an 8-inch Bache, with which some 1,300 photographs have been taken during the past year; a $2\frac{1}{2}$-inch camera of very short focus, with which the great outer spiral of the *Orion* nebula was discovered during the observations in California, and also later in Peru, the similar spiral structure of the Greater Magellanic cloud. There is also a 20-inch reflector of 45 inches focus, made by Dr. Common for the solar eclipse of 1889, and intended for the study of faint nebular detail; and a 13-inch refractor by Clark, which can be used either for visual observation, or, by reversing the crown lens and shifting the flint, can be converted into a photographic telescope.

Three new observatories, at considerable elevations, are in course of construction. A meteorological station, built at Meudon under the superintendence of M. Janssen and M. Eiffel, is in process of being conveyed to the top of Mont Blanc. The new observatory will be pyramidal in shape, and to secure as much stability as possible, two-thirds of the structure will be buried in the snow. M. Janssen has taken observations during the past year in a small temporary building, with a view to testing the stability of the snow as a foundation, and has judged the results quite satisfactory.

M. Bischoffsheim and M. Perrotin propose to erect an observatory on Mount Monnier, in the Maritime Alps, at a height of 2,800 metres. Observations will begin in 1893 April.

The Grand Duke George Mikhaïlowitch has founded an astronomical observatory at Abastouman, in Tiflis, in lat. 41°·46′ N. and long. 40°·32′ E. of Paris. M. Glasenapp has already conveyed there a 9-inch refractor, and many measures of double stars have been made in the last few months. The height of the observatory above the sea-level is 4,600 feet. A. S. D. R.

*Strassmaier and Epping's Researches on Babylonian Astronomy.*

Among the cuneiform astronomical texts which have been deciphered and explained by the joint labours of Fathers Strassmaier and Epping, there are two recently published (*Zeitschrift für Assyriologie*, 1892, pp. 220 *et seq.*) which are of very great importance. For they contain the astronomical journals

of the Babylonian observers during portions of the years 38 and 79 of the Seleucidæan era. The first embraces the period from 274 B.C. October 6 to 273 B.C. March 2, and the second that included between the dates 233 B.C. October 3 and 232 B.C. March 28. The paper in which the texts are discussed is divided into six sections. Of these the first four are occupied with the setting forth and explanation of some technical terms which occur in the astronomical nomenclature of the Babylonians, the knowledge of which is a necessary preliminary for the deciphering and full understanding of the meaning of their observations. These sections may therefore be considered as part of the very thorough discussion of the Babylonian methods of prediction and observation, and of their manner of stating the same, which has been conducted by the authors during the last eleven years. In the first section of the present paper those expressions are determined which refer to the progression and retrogression of the planets, in the second those which were employed in relation to conjunctions of the Moon and planets. For instance, one symbolical expression denoted that at the time of observation a conjunction had not yet taken place, but was imminent; another that the conjunction had occurred shortly before the recorded observation. The third section gives in tabular form the Babylonian names and symbols for the signs of the Zodiac; the fourth contains the same data for 34 normal stars, which were employed in these planetary observations according to a method already described. The stars identified in the present table are *η Piscium*; *α, β Arietis*; *η Pleiadum*; *α, β, ζ Tauri*; *α, β, γ, η, μ Geminorum*; *δ, γ, ε, θ Cancri*; *α, β, ε, θ, ρ Leonis*; *α, β, γ Virginis*; *α, β Libræ*; *α, β, δ Scorpionis*; *θ Ophiuchi*; *α, β, γ, δ Capricorni*. The remaining sections of the paper contain the observations, the transliteration of the Babylonian texts, and the corresponding translation being placed in parallel columns. We give a specimen taken from the beginning of the older of the two journals. Words in brackets are either explanatory notes, or indicate readings supplied by the authors to fill up lacunæ in the texts themselves:—

"The year 38 of Antiochus and Seleukhus the kings. Tishri 30 (*i.e.* the preceding month Elul had but twenty-nine days, and the 30th is Tishri 1st). The Moon's crescent, visible during the period of 15 time-degrees (1°=4 minutes). (On the 3rd = October 8, the Moon eastward) of *θ Ophiuchi*, one degree distant, above *Venus* distant 5 degrees . . . not seen together; the night of the 5th (= October 10) at the beginning of the night the Moon westward from *Mars*, distant 1½ degrees; the Moon 2½ degrees higher towards the north; on the 5th, clouds, the heavens (dark?); on the 7th, clouds dark. (On the 8th) the Moon eastward of *δ Capricorni*, distant 1½ degrees; on the 8th, clouds, dark; the Sun (in a halo? Equator?); on the 9th, clouds, dark; on the night of the 10th (= October 15), at the beginning of the night, the Moon eastward of *Saturn*

$1\frac{1}{2}$ degrees distant, observed earlier (*i.e.* at the time of observation conjunction had not taken place, but was imminent), clouds, dark; the Moon (moving towards the North?). On the night of the 13th, at the beginning of the night, the Moon beneath $\eta$ *Piscium*, distant $2\frac{1}{2}$ degrees; the Moon half a degree backwards (*i.e.* not actually in conjunction with the star, but half a degree to the westward)."

Interspersed among the astronomical observations are remarks appertaining to religious, social, and commercial matters, as, for instance, there is mention made of the sacrifice offered to Bel on the feast of the new Moon by the General, "the second after the king in the land of Accad," of the price of wheat and of other grains, as also of the regulation of the tariff of Babylon, according to the Grecian rate of exchange, and of the movements of the king and his body-guard. The colophon appended to the first of these two diaries reads as follows: "Observations for the feast of the New Moon from the month of Tishri of the year 37 to the end of Adar, of the year 37 of Antiochus and Seleukhus, the Kings. Not revised, not revised." That which closes the second is: "Observations for the feast of the New Moon from Tishri to the end of Adar, in the year 79 of Seleukhus, the King." To each of these journals Father Epping has added a table, which contains the reduction of the observations to the ecliptic for the year A.D. 1800, the latitude and the longitude, and in some cases the elongation from the Sun, and the angle for determining the stationary point being given for Babylonian midnight of the respective days of observation. These two important tables furnish no less than ninety-five positions of the Moon, nine of *Mercury*, twelve of *Venus*, four of *Mars*, seven of *Jupiter*, and six of *Saturn*; while there are in addition thirty-one positions distributed among twenty-three of the normal stars. We thus have astronomical observations taken more than twenty-one centuries ago, not only deciphered and explained, but reduced and presented in modern tabular form. In order that the calculations should exactly correspond to the requirements of the texts, constant collation of the one with the other and revision of the latter are necessary, thus involving a very great amount of most patient labour. But the results so far achieved by the learned authors would seem to be of the highest value, not only for the history of astronomy, but also for the detection of secular variations in the movements of the Moon and planets. We may add that Father Strassmaier has deciphered many more texts, which are at present in the hands of Father Epping, that the necessary calculations may be effected. A. L. C.

### *Variation of Latitude.*

In the Report of the Council in 1891 February, attention was called to a suspected variation in the latitude of certain places where accurate observations for latitude had been undertaken.

The question was then neither new nor old. The stability of latitude had certainly been questioned, but no systematic change, either secular or periodic, had been established. Since that time a complete change of ideas has been effected. There seems to be now distinct evidence of periodic changes in latitude, and more particularly of a rotation of the geographical round the astronomical pole in 427 days. The novelty of this hypothesis can hardly be denied. It cannot be relegated to the class of inequalities in zenith distance observations of period about a year, whose origin may be traced to temperature effects of a hundred different classes; although it will presently appear that something new has to be said even on the subject of these annual terms.

And although the merit of having stimulated the special observations and investigations which have led to the unlocking of this secret chamber, must be shared by several people, Mr. S. C. Chandler is undoubtedly to be credited with the actual finding of the key.

He was also one of the earliest to initiate the search (if we except M. Nobile, who for many years pointed out the existence of systematic errors which might be changes of latitude, without attaining to a clear demonstration of any regular law). His observations with the almucantar at Cambridge, U.S., from 1884 June to 1885 June, first suggested to him, not only the possibility of a variation in latitude, but the law of the variation. Twelve months' observations were of course not sufficient to establish a periodicity of fourteen months, though they might suggest it; and Mr. Chandler was plainly somewhat lucky in being so near the truth with his first guess. But this good fortune he supplemented by proper reserve in stating any deduction from these early observations, and by equal promptitude in following up his own line of thought when independent observations offered confirmation. This confirmation was due to Dr. Küstner, who, in his determination of the aberration from a series of observations coincident in time with those of the almucantar, came upon similar anomalies; and whose results, published in 1888, furnished a counterpart to those pointed out by Mr. Chandler in 1885.

Further evidence bearing on the question was forthcoming in the parallel determinations at Berlin, Prague, Potsdam, and Pulkowa, which showed changes in apparent latitude, not only strikingly sympathetic among themselves, but of the same range and periodicity as those noticed in 1885; and Mr. Chandler "was led to make further investigations on the subjects, which seem to establish the nature of the law of these changes, and proceeded (1891 November) to present them in due order."

The consequent series of papers in the *Astronomical Journal* can hardly fail to take its place as one of the astronomical classics. The following summary is made purposely very brief because the series is not yet complete, and no doubt much still

remains to be said on such an important subject. But it will be seen that during the year 1892 (including perhaps the end of 1891) a most important advance has been made in fundamental astronomy.

The first paper (regarding that already mentioned as preliminary) deals with the observations with the Pulkowa vertical circle (1863–1875), "which have been provocative of so much inquiry, so far without any solution of the anomalies which they show in regard to this question of latitude variation," and the Washington prime-vertical observations (1862–1867), "the most accurate determinations of declination ever made at the Naval Observatory" which yet "resulted in anomalous values of the aberration constant in the different years and a negative parallax in all." Mr. Chandler finds that a 427-day period in the latitude "furnishes the true key to the troublesome discordances in the Pulkowa latitudes," and "traces to their origin the anomalies in the Washington observations." Further, the comparison of the two series leads to the same conclusion as that already shown from the simultaneous series at Berlin and Cambridge (U.S.) in 1885 as to the *direction* of the polar motion. In the next paper it is mentioned that observations at Melbourne (1863–1884) and Leyden (1863–1867) are in complete accordance with those made at the same time at Pulkowa and Washington; and that the 427-day period accounts for the contradictory results obtained by Dr. Van Hennekeler at Leyden. The motion of the Earth's pole for the period 1860–1870 is thus fairly established. The author proceeds to consider earlier observations. In the papers numbered 3 and 4, the systematic errors of Bradley's observations, which were reduced afresh for this purpose, are discussed, particularly the collimation error. It is then concluded that the observations indicate a rotation of the pole in little more than a year and with a larger radius than that of 1860-1880, the range being about 1″. In the same paper Mr. Chandler states that Brinkley's observations at Dublin (1808–1813 and 1818–1822) are found to indicate a rotation in about a year, with range more than 1″, "wherein lies the solution of the hitherto unsolved enigma of Brinkley's singular results which led to the spirited and almost acrimonious dispute between Brinkley and Pond with regard to stellar parallaxes." The details were promised in a later paper, but have not yet been given, owing doubtless to the necessity of attending to a vitally important point which will presently appear.

In Papers V. and VI. are presented the results of an enormous mass of reductions, extending from 1837–1891, made at no fewer than seventeen observatories. The whole is broken up into forty-five series, or short groups, for the purposes of this particular discussion; and the result of this minute inquiry, confirmed (or perhaps suggested) by the observations of Bradley and Brinkley above-mentioned, seemed clear, viz., that the "instantaneous rate of angular motion of the pole has been

diminishing during the last half-century, at a sensibly uniform rate, by its one-hundred-thousandth part."

The remarkable manner in which Mr. Chandler was led to modify this statement within a few weeks is worthy of far more detailed treatment than space will here allow.

Astronomers had hesitated to accept the 427-day period, even in face of the very strong evidence of the 1860–1880 observations, owing to the difficulty in accounting for it theoretically. It had been pointed out by Euler that, treating the Earth as a rigid body, the period of rotation of the pole must be 306 days. Professor Newcomb, however, happily pointed out that a qualified rigidity (either actual viscosity or the composite character due to the ocean) afforded an explanation of this longer period; and after this suggestion Mr. Chandler's 427-day period was well and even warmly received. But the further elaboration of this hypothesis by a changing period was a new difficulty.

Professor Newcomb himself, who had reconciled the first article of the hypothesis with theory, was not slow to declare that the second was irreconcilable. Mr. Chandler's reply, in Paper VI., is a model of controversial courtesy and skill, but we can only quote a few sentences:—"It should first be said that in beginning these investigations I deliberately put aside all teachings of theory, because it seemed to me high time that the facts should be examined by a purely inductive process; that the nugatory results of all attempts to detect the existence of the Eulerian period probably arose from a defect of the theory itself; and that the entangled condition of the whole subject required that it should be examined afresh by processes unfettered by any preconceived notions whatever. . . . The appeal to observation, treated irrespective of theory, in the present series of papers, shows that a rotation of the pole really exists, but (*a*) at a daily rate of but 0°·85 (for 1875), and (*b*) that this velocity is subject to a slow retardation, which, in its turn, is not uniform. . . . The result (*a*) was at first pronounced impossible, and is even now so regarded in some quarters. Professor Newcomb, however, soon after found the defect in the theory, and is now as cordially in favour of the result given by observation as he was originally against it. . . . Now, may it not reasonably be asked if the direct deduction from observation has led to the correction of theory in the first particular, is it beyond hope that it may do so in regard to the second?"

Such a truly scientific attitude inspires confidence that the search is being rightly conducted; but the most sanguine could hardly be prepared for the reconciliation of observation and theory in the very next paper of the series, published six weeks later. By this time Mr. Chandler has rearranged his material and found, not *one variable* rotation of the pole, but *two constant* rotations (with a qualification), one in 427 days, and the other in about a year. The qualification is that the *amplitude* of the latter is apparently variable, not the period. The superposition

of these two rotations is almost exactly equivalent, for the observations available, to the law (or summary of observation as it might fairly be called) previously enounced. To make clear the novelty of this discovery it may be remarked that, although fluctuations in zenith distances of annual period have long been recognised, they have generally been ascribed to temperature effects, in which case the maxima and minima for all stations in the Northern Hemisphere should occur at the same epoch—say midsummer and midwinter. But this is not the case with the annual term now revealed. The epoch changes with the longitude, showing that the pole moves just as in the case of the 427-day term.

It is somewhat remarkable that two formulæ, differing so much in form, should be found to represent the observations almost equally well. Apparently this is to be attributed chiefly to the variability in amplitude of the annual term, and as yet this variability has not been accounted for. But to have advanced the work to this stage in such a short time is a great achievement, and much may confidently be expected from Mr. Chandler's future work. He points out, in a paper dated 1893 January 2, that the discovery of these periodic inequalities in the latitude makes it necessary to go over much old work afresh, and is himself leading the way with a discussion of the aberration constant.

In the same paper he shows that the recent results obtained at Berlin, Prague, Strassburg, Pulkowa, Rockville, and Honolulu, give a mean correction to his final formula of only five days in the epoch; "and the accordance of the separate values is high testimony to the skill of the observers, to whom astronomers owe a deep debt of gratitude for their laborious and conscientious work."

### *The Photographic Chart of the Heavens.*

During the year 1892 the actual work of forming a chart has practically been commenced at several observatories. The adverse report of the sub-committee on gauze screens led to the settlement, or rather the evasion of a definite settlement, of the vexed question of the time of exposure necessary to obtain stars of the 14th magnitude; and partly in consequence of this, partly because of other difficulties, plates of long exposure have not been taken at most observatories. But of those proper for the formation of a Catalogue, with exposures of $6^m$, $3^m$, and $20^s$ (the last supplementary exposure being proposed by the Astronomer Royal), many have been taken, and it may be hoped that the sky will soon have been covered by plates of this character. It is possible, therefore, that the history of this work may be for some years uneventful.

The first fascicule of Vol. ii. of the *Bulletin* appeared in 1892,

but the more important of its contents had already been published in anticipation, and were mentioned in the last report (*Monthly Notices*, lii. p. 292). An extract from the second fascicule has been circulated in advance by Professor Kapteyn, in which he shows, from the results obtained in the formation of the *Cape Durchmusterung*, that the light of stars near the Milky Way is richer in actinic rays than that of stars visually as bright in high galactic latitudes. His numerical result is that the excess of the photographic over the visual magnitude is found to increase 0·01 of a magnitude with each degree of galactic latitude. In a preface Dr. Gill explains that the photographs were not taken in a manner specially suited to the deduction of this important result, and that the research will be continued. This preliminary note is intended to put observers on their guard against assumptions of uniformity in the relation between photographic and visual magnitudes in different parts of the sky.

M. Trépied has published a review (of 50 pp. quarto) of the resolutions hitherto adopted by the Conference of 1887 and the subsequent committees, which will be of great value as a work of reference.

The death of Admiral Mouchez, whose energy and ability effected so much in connection with this undertaking, cannot fail to be seriously felt. He was far from seeing the completion of the great work he initiated, but it is some satisfaction to think that he lived to see the early difficulties overcome and the operations fairly commenced. The reputation of his successor at the observatory (M. Tisserand), and his expressed determination to take up this part of Admiral Mouchez's work, are matters for congratulation.

Though not directly connected with the Chart, it may be mentioned that Dr. Scheiner has measured two plates, taken with the Potsdam instrument, of the cluster in *Hercules* (13 M.), exposures $2^h$ and $1^h$ respectively, and has thus obtained the co-ordinates of 823 stars of the 12th to 14th magnitudes, the measures being closely accordant. The results (published in the *Abhand. der Kön. Preuss. Akad. der Wiss.*, Berlin 1892) bear striking testimony to the accuracy and value of the photographic method, in the particular form adopted for the Astrophotographic Chart.

## Papers read before the Society from February 1892 to January 1893.

1892.

Mar. 11. Ephemeris of the satellites of *Uranus*, 1892. A. Marth.

The reappearance of *Saturn's* ring. G. Comstock.

Results of double star measures with the 8-inch equatoreal at Windsor. New South Wales, in 1891. J. Tebbutt.

Maxima and minima of variable stars, observed during the years 1889, 1890, and 1891. J. Mitchell.

On the displacement of the apparent radiant points of meteor showers, due to the attraction, rotation, and orbital motion of the earth. J. Kleiber.

Observations of nebulæ with the 36-inch refractor of the Lick Observatory. S. W. Burnham.

A new binary star, $\beta$ 581. S. W. Burnham.

Occultation of $\gamma_1$ and $\gamma_2$ *Virginis*. Rev. A. Freeman.

The apparent places of close polar stars. A. M. W. Downing.

The new star in *Auriga*. G. Knott.

Photograph of the region of *Nova Cygni*. Isaac Roberts.

Photograph of the region of *Nova Aurigæ*. Isaac Roberts.

Preliminary note on the magnitude of the new star in *Auriga*. Professor C. Pritchard.

Ephemeris for physical observations of *Mars*, 1892. A. Marth.

Ephemeris of the satellites of *Saturn*, 1891–92 (concluded). A. Marth.

Note on the spectrum of *Nova Aurigæ*. E. W. Maunder.

On the photographic magnitude of *Nova Aurigæ*, as determined at the Royal Observatory, Greenwich. W. H. M. Christie.

On the large Sun-spot of 1892 February 5–17, and the associated magnetic disturbance, observed at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

On an annual variation in the R — D discordance. H. H. Turner.

Observations of the spots and markings on the planet *Jupiter*, made at the Dearborn Observatory, Evanston, Illinois. Professor G. W. Hough.

Apr. 8. Note on the transit of *Titan*, 1892 March 11. A. Mee.

The double star Σ 3123. S. W. Burnham.

Anderson's new star in *Auriga*. S. W. Burnham.

Observations of the reappearance of the rings of *Saturn*: observations of the position-angles of the rings and observations of the satellites. E. E. Barnard.

The new star in *Auriga*. G. Knott.

Note on the lunar theory. Professor E. W. Brown.

Ephemeris for physical observations of *Jupiter*, 1892. A. Marth.

Estimations of magnitude of *Nova Aurigæ*, made at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone.

Note on the history of the great Sun-spot of 1892 February. E. W. Maunder.

Note on the spectrum of the great spot group of 1892 February. Professor K. D. Naegamvala.

On the estimation of star magnitudes by extinction with the wedge. Captain W. de W. Abney.

May. 13. Note on the secular perturbations of the Earth by *Mars*. R. T. A. Innes.

Note on the orbit of *α Centauri*. E. B. Powell.

On the orbit of *γ Centauri*. J. E. Gore.

Comet Swift, 1892 March. H. C. Russell.

On the orbit of *γ Coronæ Australis*. J. E. Gore.

Negatives of *Jupiter* made with the great telescope of the Lick Observatory during 1891. Professor E. S. Holden and W. W. Campbell.

On the illumination of *Saturn's* rings during sunrise, and on recent observations of their reappearance. Rev. A. Freeman.

Photographs of the region of the Crab Nebula, M 1 *Tauri*. Isaac Roberts.

Photographic search for a planet beyond the orbit of *Neptune*. Isaac Roberts.

On the formulæ of reduction to apparent places of close polar stars. Professor F. Folie.

Ephemeris for physical observations of *Jupiter*, 1892 (continued). A. Marth.

On a new form of altazimuth. W. H. M. Christie.

Observations of the Moon made at the Radcliffe Observatory, Oxford, during the year 1891, and a comparison of the results with the tabular places from Hansen's Lunar Tables. E. J. Stone.

Observations of occultations of stars by the eclipsed

Moon on 1892 May 11, made at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone.

Spectrum of *Nova Aurigæ*. Rev. W. Sidgreaves.

Partial eclipse of the Moon, 1892 May 11, observed at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Observations of Swift's comet (*a* 1892) made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Estimations of the magnitude of *Nova Aurigæ*. J. G. Lohse.

On a diagram useful as a guide in adjusting a diffraction grating spectroscope. H. F. Newall.

Comparison of magnitudes of *Nova Aurigæ* and neighbouring stars, made with the Newall telescope at the Observatory, Cambridge. H. F. Newall.

On a pretended early discovery of a satellite of *Mars*. Dr. R. Copeland.

June 10. Ephemeris of the satellites of *Mars*, 1892. A. Marth.

The lunar eclipse, 1892 May 11; observations made at Mr. Crossley's Observatory, Bermerside, Halifax. E. Crossley and J. Gledhill.

On a parallel plate double image micrometer. J. H. Poynting.

Occultations and other phenomena of the lunar eclipse, 1892 May 11. Rev. A. Freeman.

Orbit of 9 *Argûs*, $\beta$ 101. Professor S. Glasenapp.

List of the proper motions in the line of sight of 51 stars. Professor H. C. Vogel.

The orbit of O $\Sigma$ 269. J. E. Gore.

Observations of Wolf's periodical comet made at the Cambridge Observatory with the Northumberland equatoreal and square bar micrometer. Communicated by the Secretaries.

Photograph of the region of the globular cluster 15 M *Pegasi*. Isaac Roberts.

Photograph of the nebula H V. 15, near 52 *Cygni*. Isaac Roberts.

Observations of Comet *a* 1892 (Swift), made at the Royal Observatory, Cape of Good Hope. Communicated by David Gill.

Observations of Swift's Comet (*a* 1892), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Occultation of 73 *Piscium* by *Jupiter*, 1892 May 23, observed at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Orbit of the double star $\kappa$ *Pegasi* (A C). Professor S. Glasenapp.

Data for computing the positions of the satellites of *Jupiter*, 1892. A. Marth.

Note on Damoiseau's *Tables écliptiques des satellites de Jupiter*. A. M. W. Downing.

Photograph of $\eta$ *Argûs*. H. C. Russell.

Sextant observations of comet Swift. Captain G. T. Parson.

The opposition of *Mars*, 1892. E. J. Stone.

Nov. 11. Note on the conjunction of *Venus* and *Jupiter* observed in Australia 1892 February 6. A. Marth.

Observations of phenomena of *Jupiter's* satellites at Windsor, New South Wales, in the year 1891. J. Tebbutt.

The orbit of *Flora*; with corrections to Brünnow's *Tafeln der Flora*. A. M. W. Downing.

Observations of Swift's Comet (*a* 1892), and Winnecke's periodical comet, made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Observations of U *Orionis*. Lieut.-Col. E. E. Markwick.

Greenwich mean times of superior and inferior geocentric conjunctions of *Jupiter's* fourth satellite (*Callisto*) from 1892 November to the end of 1893. Communicated by the Superintendent of the *Nautical Almanac*.

Sextant observations of Swift's Comet. Capt. G. M. Lourison.

Observations of the variable star S *Ursæ Majoris*. C. E. Peek.

The orbit of $\gamma$ *Coronæ Australis*. R. P. Sellors.

The motion of $\zeta$ *Cancri*. S. W. Burnham.

The new star in *Auriga*. S. W. Burnham.

On the orbit of $\Sigma$ 2525. J. E. Gore.

On the systematic errors of the Moon in right ascension. H. H. Turner.

Probable error of the clock correction when both the clock rate and the instrumental constants are found by a least squares solution of a single night's observations. Rev. J. T. Hedrick.

Enlarged star and Moon photographs. H. C. Russell.

Observations of Brooks' Comet (*d* 1892) and Swift's Comet (*a* 1892), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

On the sidereal period of the new satellite of *Jupiter*. Rev. A. Freeman.

*Nova Aurigæ*. E. E. Barnard.

Discovery of a comet by photography. E. E. Barnard.

Note on the period and distance of the fifth satellite of *Jupiter*. E. E. Barnard.

Corrections to Hansen's *Tables de la Lune*. J. Gordon.

On the variation of latitude as indicated by recent observations at the Royal Observatory, Greenwich. W. G. Thackeray and H. H. Turner.

On the photographic magnitude of *Nova Aurigæ*, as determined at the Royal Observatory, Greenwich. W. H. M. Christie.

Estimations of magnitude of *Nova Aurigæ*, made with the Barclay Equatoreal at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone.

Observations of Holmes' Comet (*f* 1892), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

On the best form of mounting for a large reflector. A. A. Common.

Dec. 9. On the spectrum of the new star in *Aurigæ*, as compared with spectra of planetary nebulæ. E. von Gothard.

The lunar eclipse, 1892, May 11–12. G. J. Newbegin.

Observations of Winnecke's periodical comet at Windsor, New South Wales. J. Tebbutt.

The binary star Σ 1785. S. W. Burnham.

Photographs of Comet Holmes. Isaac Roberts.

Observations of Holmes' Comet, made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Elements of Comet Holmes. E. Roberts.

Note on an occultation of D.M. + 4°·123 (mag. 6·5) by *Mars* on 1893 January 14. A. M. W. Downing.

1893.

Jan. 13. The secular perturbations of the Earth arising from the action of *Venus*. R. T. A. Innes.

The eclipse of the Moon, 1892 November 4–5, observed at Sydney Observatory. Communicated by H. C. Russell.

Observations of the phenomena of *Jupiter's* satellites at Bermerside Observatory, Halifax, in the year 1892. J. Gledhill.

Note on the Red Spot on *Jupiter*. J. Gledhill.

Observations of the phenomena of the satellites of *Saturn* at Bermerside Observatory, Halifax, in the year 1892. J. Gledhill.

Ephemeris of *Juno* near the time of opposition, 1893, computed from the corrected elements published in *Monthly Notices*, vol. l. p. 495. Communicated by the Superintendent of the *Nautical Almanac*.

Opposition of *Mars*, 1892; observations made at the Royal Observatory, Cape of Good Hope. David Gill.

*Nova Aurigæ.* Isaac Roberts.

Photograph of the nebula H I. 55 *Pegasi.* Isaac Roberts.

Photograph of the cluster H VI. 30 *Cassiopeiæ.* Isaac Roberts.

The *Geminid* meteor shower. W. F. Denning.

Observations of Brooks' Comet (*g*, 1892), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

On the variation of latitude by the Greenwich transit-circle observations. S C. Chandler.

Ephemerides of the satellites of *Saturn*, 1893. A. Marth.

On the determination of the equations for the perturbation of the inclination and node of an orbit by the method of variation of constants. R. Bryant.

Estimations of magnitude of *Nova Aurigæ*, made at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone.

Latitude variation and Greenwich observations, 1851–91. W. G. Thackeray.

Observations of occultations of stars by the Moon, and of phenomena of *Jupiter's* satellites during the year 1892. Communicated by the Astronomer Royal.

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Georgetown College Observatory.
Göttingen, Royal Observatory.
Göttingen, Royal Society of Sciences.
Haarlem, Teyler Museum.
Halle, Leopold-Caroline Academy of Naturalists.
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Haverford College Observatory.
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Rome, Royal Academy *dei Lincei*.
Rome, Vatican Observatory.
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Tiflis, Physical Observatory.
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Turin, Royal Academy of Sciences.
Turin, Royal Observatory.
Vienna, Austrian Geodetic Commission.
Vienna, Imperial Academy of Sciences.
Vienna, Imperial Observatory.
Vienna, International Geodetic Bureau.
Washington, National Academy of Sciences.
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# ADDRESS

*Delivered by the President, Mr. E. B. Knobel, on presenting the Gold Medal to Professor H. C. Vogel.*

The Council have awarded the Gold Medal to Dr. Hermann Carl Vogel for his "Spectroscopic and Other Astronomical Observations," and it is now my privilege to lay before you some of the considerations which have influenced them, in bestowing the highest honour in their power, upon the Director of the Astrophysical Observatory at Potsdam.

In reviewing the numerous observations and researches, conducted with such refinement and high intelligence as distinguishes Dr. Vogel's career as an astronomer, it is, perhaps, natural that our attention should first be given to those spectroscopic investigations by which he has more conspicuously enriched our science, and in which he has developed a precision that is both exceptional and remarkable.

It seems probable, that researches in stellar astronomy which depend upon the analysis of the light emitted by the stars, will afford us in some respects results available for more exact conclusions, than those made by the ordinary methods of observation and measurement. By the latter, we are able to determine the movements of stars transversely to the line of sight, but only in angular measures, which, save in a very few cases, cannot be translated into units of distance, and in those instances the probable errors are very large. But, incredible as it would seem, the spectroscope, wielded with such delicate and refined skill as characterises the researches we have to consider, teaches us the velocity at which stars are approaching or receding from the earth, with a probable error which may be even less than a mile per second of time.

Such precision as has been attained, reveals to us a means of partially unravelling some of the complexities of the stellar movements, and enables us to penetrate into some of the mysteries of the universe of stars, which a few years ago would have been considered altogether beyond the human intellect to unfold. Not only are we thus able to ascertain the general drift of stars and star-systems, but also to obtain an imperishable record of the internal motions within those systems.

The physical principle underlying such investigations, is of a sufficiently simple character; and was first suggested by Doppler

in 1841, as an extension of the principle on which he had shown that a sound should become sharper or flatter, if there were an approach or a recession between the ear and the source of the sound. Doppler supposed that stars might in this way change their colour as observed by eye, but he did not know of the stores of invisible light beyond both limits of the visible spectrum, ready to be lowered or raised into visibility, so that, as a matter of fact, no such change of colour would occur.

In 1848, Fizeau investigated the theory of Doppler with regard to sound, and offered an experimental proof of its correctness; and, in applying it to light, he pointed out the importance of considering the individual wave-lengths, and mentioned that though the enormous velocity of light presented a great difficulty in any experimental demonstration, he nevertheless expressed a confident belief that such proof would eventually be forthcoming. But it was not until spectrum analysis had enabled us to detect the lines of terrestrial substances in the stars, that this principle, in the hands of Huggins, became, in 1868, of practical importance in astronomy.

Eight years ago the high value of physical researches on the motion of stars in the line of sight, was acknowledged by the Council, in awarding the Gold Medal to him, to whom the honour justly belongs of originating this branch of observational astronomy—our Foreign Secretary, Dr. Huggins.

In the address delivered on that occasion by the President, Mr. Dunkin, the history of Dr. Huggins's important researches was clearly set forth, and it will be remembered that his observations were first published in the *Philosophical Transactions* for 1868.

About this time, Dr. Vogel commenced astrophysical investigations at the University Observatory of Leipzig, his interest in this study having been excited by his acquaintance with Zöllner; and in 1869, not long after the important discovery of Lockyer and Janssen, he assisted Zöllner in his spectroscopic observations of the solar prominences. But on his appointment to Von Bülow's private observatory at Bothkamp in 1870, he devoted himself more particularly to stellar spectroscopy, and prominently to that branch which had yielded Dr. Huggins such brilliant results.

It must be remembered that at this time the subject was young, and it had been shown by its founder that the utmost accuracy in the construction of the apparatus employed was essential. Instruments had to be invented and their errors determined with the greatest nicety; and Dr. Vogel's appreciation of these difficulties was well manifested in his minute attention to the details of his apparatus.

The spectroscope he employed, was constructed by Schröder, and consisted of five direct vision prisms, with a refracting angle of 90°. The special features of the instrument were—the object glass of the telescope being of the same aperture and focal

length as the collimator lens, and the size of the latter being adapted to the cone of light coming from the object glass of the large 11½-inch refractor, so that all the rays could be made use of. Great stability was insured by special supports, and the performance of the instrument left nothing to be desired.

The comparison hydrogen-spectrum was so arranged, that the bright lines of the gas spectrum should extend across the whole field of view of the telescope. In this way the bright lines were seen on either side of the band-like stellar-spectrum, and thus any error from the estimation of coincidence of two lines, on one side only, was eliminated.

With this apparatus, Dr. Vogel, in the year 1871, observed and measured the principal lines in the spectra of several stars, reducing them to wave-lengths, and adopting the scale given in Ångström's chart. He measured the displacement of the F hydrogen line in the spectra of *Sirius*, *Procyon*, *Capella*, *Altair*, and *Vega*, and his determination of their motions in the line of sight, published in the *Astronomische Nachrichten*, was strikingly confirmatory of the results previously obtained by Huggins.

Viewing these observations under the light of more recent researches, it must be admitted that the instrumental means employed were hardly adequate for so delicate an inquiry, and the amount of these motions must necessarily be considered only as approximate.

For four years Dr. Vogel pursued his spectroscopic researches at the Bothkamp Observatory, not only in measuring the spectra of stars, and the determination of their motions in the line of sight, but in other directions which will be referred to later on. It may be sufficient to say here, that it was the excellence and success of his work at this observatory, in so many new directions, that led to the founding of the Astrophysical Observatory at Potsdam in the year 1874. Of the extent and importance of the work done at this institution, through the origination, and under the superintendence, of Dr. Vogel, the eight volumes of published results bear ample testimony.

For fifteen or sixteen years, the method of determining the motions of stars in the line of sight had remained undeveloped from the condition in which it left the hands of Huggins, and no progress was made in the accuracy attained by him. But about the year 1887, experiments were made at Potsdam by a photographic application of the method, which showed that a sufficiently great dispersion could be made use of, to readily detect and measure the displacement of the spectral lines produced by the radial motion of the stars.

In his memoir already referred to, published in 1868, Dr. Huggins mentions that the chief difficulties he had to encounter, in spectroscopic observations of the stars, arose from the unsteadiness of the atmosphere. Unless the air is very steady, the lines were seen too fitfully to permit of any certainty in the determination of coincidences of the degree of delicacy required

in his investigations. He says that he "passed hours in the attempt to determine the position of a single line, and had then not considered that the numerous observations which he had obtained were possessed, even collectively, of sufficient weight to establish with any certainty the coincidence of the line with the one compared with it." One remarkable result of Dr. Vogel's photographic method, was the discovery that the disturbances of the atmosphere exert their influence in a lesser degree on the photograph than on the eye in direct observations. Such unsteadiness in our atmosphere, as would defeat all attempts at accurate eye observation, is of little consequence when the rays are allowed to fall upon the sensitive photographic plate. The continually varying refractions which cause the star image to be at one instant on the slit of the spectroscope, and the next instant off it, appear to be of small moment, for they only affect the time of exposure. The plate faithfully records all the rays that fall upon it, however rapidly these alternate appearances and disappearances recur.

The application of photography to the determination of the motions of stars in the line of sight, in the hands of Dr. Vogel, assisted by Dr. Scheiner, has yielded results which are nothing short of surprising; and the investigation has been conducted with such refined and scrupulous attention to the elimination of errors, as renders it worthy of our highest acknowledgment.

These researches are contained in the seventh volume of the Publications of the Astrophysical Observatory at Potsdam, and the observations were made in the years 1888 to 1890.

In the construction of the apparatus—called the Spectrograph—the following points were taken into consideration:—Great stability for the smallest possible weight; suitable dimensions of prisms, collimator, and camera objectives, in order to preserve sufficient brightness with the greatest possible dispersion; accurate adjustment of the photographic plate in the focal plane of the camera objective; and exact keeping of the star on the slit of the spectrograph. The first two conditions were satisfied by making the frame of cast steel, and by giving it a form which offered the greatest possible resistance to flexure. The detailed construction of the apparatus has already been given in the publications of the Society, and further repetition is hardly necessary. Suffice it to say that the utmost attention was given to secure such stability that very small displacements of the lines in the stellar spectra could be photographed and measured.

The performance of the instrument was tested on the Sun by direct observations, and by photographs; and the accuracy of the measures, as well as the correctness of the adjustment, are well and most satisfactorily indicated by the following observations of the motion of *Venus*:—

| | Observed Velocity. | Calculated Velocity. |
|---|---|---|
| 1889 Jan. 2 | −7·8 | −7·4 English miles |
| Feb. 10 | −7·4 | −7·8 „ |

No better proof than these figures afford, could be given of the refinement which Dr. Vogel has introduced into every part of his work. In particular, he has taken the greatest precaution in respect of the insidious influence of changes of temperature on the apparatus generally, and especially in the comparison of stellar photographs under the microscope with solar ones taken at a different temperature.

He has employed different methods of measurement under the microscope of the displacement of the stellar lines relatively to the artificial ones, according to the type of star and the character of its lines. These are, however, of too technical a nature for detailed description on this occasion, and I must therefore refer to his original memoir, where every part of his investigation is fully described. Mention should, perhaps, be made of his employment of the spectrum of iron for comparison with *Sirius* and some other stars. He was thus able to measure the displacement in as many as eleven different iron lines compared with stellar ones.

The first important result obtained, was the proof of the influence of the Earth's motion on the displacement of the lines, which the earlier direct observations had failed to show with accuracy. As examples, I quote the results for three stars.

| | Observed Velocity. | Earth's Velocity. | Velocity of Star reduced to the Sun. | |
|---|---|---|---|---|
| | | *α Tauri.* | | |
| 1888 Oct. 28 | +18·1 | − 9·5 | +27·6 | English miles |
| Nov. 10 | +24·9 | − 5·9 | +30·8 | ,, |
| Dec. 4 | +30·6 | + 1·8 | +28·8 | ,, |
| 1890 Jan. 9 | +43·7 | +12·3 | +31·4 | ,, |
| | | *α Ophiuchi.* | | |
| 1888 Sept. 30 | +27·6 | +14·1 | +13·5 | ,, |
| 1889 June 7 | + 9·7 | − 1·0 | +10·7 | ,, |
| | | *α Ursæ Majoris.* | | |
| 1888 Nov. 7 | −17·0 | −11·9 | − 5·1 | ,, |
| 9 | −18·1 | −11·9 | − 6·2 | ,, |
| 1889 May 4 | + 5·2 | +11·8 | − 6·6 | ,, |
| 22 | + 3·4 | +11·2 | − 7·8 | ,, |

The consideration of these remarkable results will at once suggest the question: May we not be able, in the future, by the spectroscopic measurement of the radial motions of stars, to determine the earth's velocity in her orbit? In that case, we shall be forced to the astounding conclusion that by observations

of stars, whose parallactic displacement is absolutely insensible, we are yet able to determine the important unit of measurement in our system—the solar parallax.

The difficulties in the early observations arising from atmospheric tremor, to which I have already referred, disappear in great measure when a much more powerful spectroscope is employed, so that the difference of position between the star line and the comparison line, is much more obvious to the eye. Especially is this the case when the great dispersion of a modern grating is made use of.

Armed with these advantages, Keeler has shown that on *objects which are bright enough*, the eye can well hold its own as compared with the photographic plate. His measures of *Venus* show well what the eye can do.

*Venus.*

| | Observed Motion. | Calculated Motion. |
|---|---|---|
| 1890 Aug. 16 | −7·3 | −8·1 miles |
| 22 | −8·9 | −8·2 „ |
| 30 | −7·3 | −8·3 „ |
| Sept. 3 | −8·3 | −8·3 „ |
| 4 | −8·2 | −8·3 „ |

It is especially gratifying to find that, in the case of a star of sufficient brightness, and which possesses a suitable spectrum, the eye observations at the Lick Observatory agree minutely with the results of the measurements of the photographic plates at Potsdam.

*Arcturus.*

Mean of observations at Potsdam −4·4 ± 0·2

Mt. Hamilton (Keeler).

| | | |
|---|---|---|
| 1890 Apr. 10 | −4·6 | miles |
| Aug. 7 | −4·0 | „ |
| 15 | −4·2 | „ |
| Mean | −4·3 | |

There can now be no longer any hesitation in accepting the motions which Dr. Vogel has given us of his fifty-one stars, as, indeed, very near the truth; and in recognising the immense importance of this method of astronomical observation.

The photographic work at Potsdam has not only given to us the radial motions of fifty-one stars, but from it have resulted two discoveries of very high interest—namely, the compound nature and true cause of the variability of *Algol*; and the duplicity of *Spica*, where, from the inclination of the orbit relatively to the

line of sight, no variation of its light is produced by its obscure companion.

Indeed, at Harvard, the discovery of two remarkable binary stars had already been made—namely, *ζ Ursæ Majoris*, and *β Aurigæ*, but the Harvard photographs, taken with a slitless form of spectroscope (the prisms being arranged before the object glass of the telescope in the manner first used by Fraunhofer, and later revived by Secchi), do not permit of a direct comparison of the star's spectrum with terrestrial spectra.

In the case of the binary star *Algol*, only one star is bright, and, consequently, there would be no doubling of the lines as shown in the Harvard photographs of *β Aurigæ*, but only a small shift of the lines to and fro in the spectrum, as the bright star moved in its orbit towards or from the Earth, and this would need for its detection the fiducial positions of terrestrial lines for comparison with them.

Twelve photographs of *Algol*, taken by Dr. Vogel in the years 1888 to 1891, when his researches on stellar motion terminated, were measured independently by him and by Dr. Scheiner, and the comparison of their results, when reduced to the Sun, show, what is practically, perfect agreement. From the discussion of the displacement of the lines, our Medallist made the interesting discovery of a motion of approach and recess, corresponding to the known variation of its light of 68·8 hours.

Thus, the explanation suggested by Goodricke, a century ago, that the variability of *Algol* was due to the periodic transit of an opaque body revolving round the star, was proved to be the true one.

The Potsdam photographs show that before minimum the bright star is receding at the rate of 24·4 English miles a second, while after the minimum has been passed the star approaches us with the velocity of 28·6 miles a second. From these velocities it follows that the system of *Algol* is approaching our system at the rate of 2·3 miles a second, and that the visible star has a velocity in its orbit of 26·3 miles. Assuming that both the bright and dark components have the same density, so that their masses are directly as their volumes, Dr. Vogel gives the following particulars of the system :—

| | English Miles. |
|---|---|
| Diameter of *Algol* ... ... ... ... | 1,061,000 |
| Diameter of dark companion ... ... ... | 830,300 |
| Distance of centre ... ... ... ... | 3,230,000 |
| Motion of *Algol* in its orbit ... ... ... | 26·3 miles per second |
| Motion of companion ... ... ... ... | 55·4 „ „ |
| Mass of *Algol* ... ... ... ... ... | $\frac{4}{9}$ of Sun's mass |
| Mass of companion ... ... ... ... | $\frac{2}{9}$ „ |

In the case of *Spica* the method followed was to photo-

graph on the same plate the spectrum of the star and that of terrestrial hydrogen, and the displacement of the star lines was measured with the microscope. These measurements were made with considerable difficulty, owing to the fact that the hydrogen lines in the spectrum of this star are broad and ill-defined; and in this and similar cases a special method had in consequence to be adopted. The result of the measurement of twenty-seven photographs, was to show that the star lines are displaced alternately towards the red and violet ends of the spectrum, in a complete period of about four days, the maximum displacement towards the violet, indicating a motion towards the Sun of 65·9 English miles, and that towards the red, a receding motion of 47·5 miles.

These observations are completely explained on the supposition that *Spica* is a binary star, one component of which is too faint to be detected by any means at present at our disposal. The orbital velocity of the bright star is 56·7 miles a second, and the system is approaching the Sun at the rate of 9·2 miles a second. The following are the elements:—

*α Virginis.*

Velocity in line of sight − velocity of system = $56{\cdot}7 \sin\left(\frac{t-t_0}{p}\right) 360°$ in miles

Velocity of system = − 9·2 miles

Period $p$ = 4·0134 days

Epoch $t_0$ = 1890 May 4, $10^h{\cdot}50$ Potsdam m. t.

Assuming a circular orbit, and that the components have equal mass, then the mass of the system is 2·6 times that of the sun, and the components are separated by about $6\frac{1}{4}$ millions of miles. Taking the most probable value for the star's parallax, the angular separation of the stars would be $0''{\cdot}014$, a quantity far too small to be detected by the most powerful telescopes.

It should be mentioned that Dr. Vogel conceives that some traces of the spectrum of the faint companion can be made out in the photographs, in the unsymmetrical appearance of the hydrogen lines at the time of maximum motion, and a greater sharpness of other lines at the time of minimum motion.

The new light thrown upon the constitution of the heavens by these remarkable discoveries excites our imagination in the highest degree, and may easily lead us into the wide fields of conjecture and speculation; for there can be little doubt that many such systems exist, which future observations will make known to us. The spectacle of two suns, each as large as our own, revolving round each other in a few days, is one that has been revealed to us by indirect means it is true; but it is also true that the evidence depends upon laws and principles so well investigated, and so well understood, that what might

otherwise bear the aspect of romance, must be accepted as a logical, scientific, and indisputable deduction.

Before passing from this subject, I should not omit to state that shortly after Dr. Huggins's original observations, the new method of observation of radial motions was taken up systematically at the Royal Observatory, Greenwich, and at the Temple Observatory, Rugby. From 1874 until 1890 the work was pursued assiduously at Greenwich, and every observation made has been communicated to the Society and published in the *Monthly Notices.*

To secure accurate data by which posterity may be able to recognise the changes that are possibly continually, and progressively, taking place in the heavens, is an important duty that devolves upon us in return for the enormous advantages and facilities which modern scientific research has placed at our disposal. It was the recognition of this obligation that brought about the recent international organisation for the construction of a photographic chart of the heavens, and it was the same consideration in the mind of our Medallist that led him to commence the laborious work of a Spectroscopic *Durchmusterung.* To this intent, Dr. Vogel, assisted by Dr. Müller, in the years 1880 to 1882, observed the spectra of all stars to the 7·5 magnitude situated in the zone between the parallels of 1° south and 20° north declination.

The results were published in the third volume of the publications of the Potsdam Observatory, and form a catalogue of the spectra of 4,051 stars.

It is very gratifying to note that this important undertaking has now been completed between the Pole and 15° south declination: the observations between the Equator and −15° having been made by Dr. Konkoly at the O'Gyalla Observatory, and those from 20° north declination to the Pole by Dr. Dunér.

The spectra of the stars examined by Dr. Vogel are classified according to the three types of the system adopted by him. It will be remembered that from his voluminous researches he had been led to a classification of stellar spectra differing somewhat from that adopted by Secchi, inasmuch as he combines the third and fourth types of the latter physicist, into one division. Accepting the hypothesis of Zöllner, that yellow and red stars are simply white stars in various stages of cooling, he considered the white stars of Class I. as the hottest and youngest members of the sidereal family; those of the Solar type, as having wasted much of their store of radiation; while the red stars with banded spectra are viewed as "effete suns hastening rapidly down the road to final extinction." But whatever views may come to be adopted ultimately of the relation to each other of the different stellar types, Dr. Vogel's system of arrangement has been of considerable assistance in the record and comparison of stellar spectra.

In solar physics Dr. Vogel's researches place him in the

forefront of those who have laboured at this branch of astronomy, created by the invention of the spectroscope. While at Bothkamp numerous observations were made, and the discoveries that resulted are of much interest.

It had occurred to both Secchi and Zöllner, that from the unequal displacement of the F or the C line, when observed at the two opposite points of the Sun's equator, the velocity of solar rotation might be ascertained. If a spectrum line be observed on the eastern limb of the Sun, which is approaching the observer, it will, in comparison with its position in the centre of the disc, appear to be displaced towards the violet, whereas observations of that line on the western limb, which is receding from us, would show a displacement in the opposite direction. For such a delicate investigation, Zöllner had invented a Reversion-Spectroscope, by which instrument two spectra could be brought into juxtaposition, but with the lines in reverse order, so that the measurable effect of any displacement of the lines would be doubled, as the deviation in each spectrum is in an opposite direction.

With such an instrument Dr. Vogel, in 1871, at Bothkamp, while observing the Sun's limb, was able to detect an undoubted displacement of the F line, the cause of which was traceable to the Sun's rotation, and thus for the first time the *fact* of rotation was proved by the spectroscope.

This method of determining the rotation of the Sun, has recently been very successfully developed by Dr. Dunér, who has succeeded, not only in measuring the displacement of the lines on the solar equator, and so measuring the velocity of equatorial rotation, but has also been able to measure the diminution of the angular velocity of rotation in higher heliocentric latitudes, which had been discovered from observations of sunspots.

No better test, if such were needed, could be devised of the soundness of the conclusions as to the cause of such displacements in the observations of stellar spectra.

In the year 1877 the intensity of solar radiation occupied the attention of Dr. Vogel. It had been earlier remarked by Secchi in his investigation of the absorption of the solar atmosphere on the luminous rays, that the light from the limb of the Sun is not white, but reddish-brown. This indication of selective absorption, showed the importance of investigating by some photometric method, the loss suffered by rays of different refrangibilities.

Our Medallist was thus led to design a new spectrum-photometer, which was constructed on the principle of the polarising photometer invented by Glans. The results he obtained with this instrument are of the greatest interest.

In his skilful hands, he was able to compare with great accuracy and directly, the brightness of the rays of different refrangibilities proceeding from different parts of the Sun's disc.

The results are contained in the following table. In the first

column is given the distance of the point from the Sun's centre in percentage of the Sun's radius, and the other columns give the ratio between the light of the given colour at the centre and at the given point.

| D | Violet $\left.\begin{matrix}412\\405\end{matrix}\right\}\mu\mu$ | Dark Blue $\left.\begin{matrix}446\\440\end{matrix}\right\}\mu\mu$ | Blue $\left.\begin{matrix}473\\467\end{matrix}\right\}\mu\mu$ | Green $\left.\begin{matrix}515\\510\end{matrix}\right\}\mu\mu$ | Yellow $\left.\begin{matrix}585\\573\end{matrix}\right\}\mu\mu$ | Red $\left.\begin{matrix}666\\658\end{matrix}\right\}\mu\mu$ |
|---|---|---|---|---|---|---|
| 0 | 100·0 | 100·0 | 100·0 | 100·0 | 100·0 | 100·0 |
| 5 | 99·9 | 99·9 | 99·9 | 99·9 | 99·9 | 100·0 |
| 10 | 99·6 | 99·7 | 99·7 | 99·7 | 99·8 | 99·9 |
| 15 | 99·2 | 99·3 | 99·3 | 99·3 | 99·5 | 99·7 |
| 20 | 98·5 | 98·7 | 98·8 | 98·7 | 99·2 | 99·5 |
| 25 | 97·5 | 97·8 | 98·1 | 97·9 | 98·8 | 99·3 |
| 30 | 96·3 | 96·8 | 97·2 | 96·9 | 98·2 | 98·9 |
| 35 | 95·0 | 95·6 | 96·1 | 95·7 | 97·5 | 98·5 |
| 40 | 93·4 | 94·1 | 94·7 | 94·3 | 96·7 | 98·0 |
| 45 | 91·2 | 92·2 | 93·1 | 92·6 | 95·7 | 97·4 |
| 50 | 88·7 | 90·2 | 91·3 | 90·7 | 94·5 | 96·7 |
| 55 | 85·7 | 87·8 | 89·3 | 88·6 | 92·9 | 95·9 |
| 60 | 82·4 | 84·9 | 87·0 | 86·2 | 90·9 | 94·8 |
| 65 | 78·7 | 81·7 | 84·2 | 83·4 | 88·0 | 93·2 |
| 70 | 74·4 | 77·8 | 80·8 | 80·0 | 84·5 | 91·0 |
| 75 | 69·4 | 73·0 | 76·7 | 75·9 | 80·1 | 88·1 |
| 80 | 63·7 | 67·0 | 71·7 | 70·9 | 74·6 | 84·3 |
| 85 | 56·7 | 59·6 | 65·5 | 64·7 | 67·7 | 79·0 |
| 90 | 47·7 | 50·2 | 57·6 | 56·6 | 59·0 | 71·0 |
| 95 | 34·7 | 35·0 | 45·6 | 44·0 | 46·0 | 58·0 |
| 100 | 13·0 | 14·0 | 16·0 | 16·0 | 25·0 | 30·0 |

The consideration of these figures shows that of the violet rays, only 13 per cent. penetrate the solar atmosphere at the limb, of the indigo 14 per cent., of the blue and green 16 per cent., 25 per cent. of the yellow, and 30 per cent. of the red.

From the complete analysis of the Sun's light from the centre to the edge of the disc afforded by the above table, we see that the colour at the limb must be different from that at the centre of the disc, since more of the violet rays are absorbed than the red. The observations show, also, a much more rapid degradation of the light towards the limb, and so indicate a thin and dense atmosphere. In discussing his results, according to the fundamental law of radiation that an incandescent sphere appears sensibly of equal brightness all over, the foreshortening of each area inclined to the line of sight compensating for its diminished radiation, Dr. Vogel finds that if the absorbing

envelope of the Sun were removed, the brightness of the red rays of the visible spectrum would be increased about 1·49 times, and the violet rays 3·01 times.

The rapid development of spectroscopy soon rendered necessary a reconstruction and completion of Ångström's Map of the Solar Spectrum. This work, which was first undertaken by Mr. Lockyer, was subsequently taken up by Dr. Vogel at Potsdam, who made a long series of accurate measures, and took a vast number of photographs between F and H—from 489 to 389 millionths of a millimetre of wave-length; and the result is a map of this portion of the solar spectrum no less than 17 feet long. The less refrangible end was later completed by Dr. Müller. Under Dr. Vogel's superintendence, Drs. Müller and Kempf made original determinations of the wave-lengths of 300 lines, by the aid of which the wave-lengths of all the lines in the Potsdam map were newly fixed with an accuracy considerably greater than that of the scale of Ångström, then almost exclusively in use.

Not the least valuable of the spectroscopic observations, pursued with the same unwearying assiduity by our Medallist, are those he made on the spectra of the planets.

In examining the spectra of bodies like the planets, which shine solely by the reflected light of the Sun, the only differences from the solar spectrum we should expect to find, would be those due to the absorbing influences of their atmospheres. Such absorption bands had been measured in the principal planets by Huggins and Secchi, but at Bothkamp Dr. Vogel succeeded in making the most complete measurements we possess of the lines in the spectra of all the planets, and determined the refrangibility of the principal absorption bands. The interesting question of the causes of some of these bands is at present undecided, and though the observations indicate the existence of aqueous vapour in the atmospheres of some of the planets, yet bands were observed by him in the spectra of *Jupiter*, *Saturn*, and *Uranus*, which suggest a difference in the constitution of the gaseous envelopes surrounding those planets compared with that of our terrestrial atmosphere. For these important researches Dr. Vogel was awarded a prize by the Copenhagen Academy.

Besides observing the spectra of Nebulæ, Clusters, and Comets, he, in 1871, instituted measures of the bright lines visible in the spectrum of the Aurora, and determined with great exactness the wave-lengths of about seven lines. Hitherto the identification of the Auroral spectrum has not been satisfactorily established, the principal line in the green being quite unknown. Dr. Vogel, however, was strongly inclined to the opinion that the spectrum is merely a modification of that of air, but the origin of these lines is still an open question.

The spectrum of Lightning also engaged his attention, and, notwithstanding the difficulty of such observations, the positions of the brightest lines were accurately measured by him and Dr.

Lohse with the stellar spectroscope of the Bothkamp Observatory. Suffice it to say that his observations appear to have been fully confirmed by those made more recently.

In determining this award the Council desired to include other astronomical researches of Dr. Vogel, apart from those depending on the spectroscope, and it is my duty here to allude to them, though in the briefest terms.

While an assistant at the Leipzig Observatory he made two important series of observations on nebulæ and clusters, in which the positions of about 240 of these objects were determined with an exactness sufficient to make them of great value in any discussion of nebular parallax. In this respect these observations of Dr. Vogel have probably not been surpassed. At this period, also, he prepared a memoir giving the results of his micrometric measures and photometric determination of 176 stars, ranging from 6·5 to 13 magnitude, in one portion of the great cluster in *Perseus*; the investigation of the other portion of this double cluster having been previously made by Krüger at Helsingfors. In this work, the care exercised in the determination of the zero of position, and in the investigation of the micrometer, are characteristic of the author; and the accuracy of the results is satisfactorily shown by the very small probable errors of the positions of the brighter stars, and by the indication in one of them, of a possible parallax of 0″·3. In undertaking these researches his object was to fix relative positions, so that any future change might be detected. Probably, however, in the future we shall rely more upon the photographic astronomer to discover and inform us of changes in the heavens, than upon such laborious investigations as those made with the micrometer.

Finally, I would desire to refer to our Medallist's observations of *Jupiter's* satellites.

The determination of the mass of *Jupiter* has been repeatedly undertaken, and the values we possess of this important constant, have been derived either from heliometer measures, and transit observations of the satellites, or from planetary perturbations. In order to furnish additional data for such an inquiry, Dr. Vogel, while at Leipzig, made a long series of transit observations of the 3rd and 4th Satellites. These observations have been used by Dr. Kempf in his investigation of the mass of *Jupiter* contained in the third volume of the Potsdam publications, in which he combines the most reliable researches that had been made on the subject. His definitive result of $\frac{1}{1047{\cdot}700}$ differs insensibly from the value of $\frac{1}{1047{\cdot}767}$ derived from Dr. Vogel's observations alone. This satisfactory agreement indicates clearly the excellence of his Leipzig observations, which were made in the years 1868 to 1870.

In the brief and very imperfect review of Dr. Vogel's labours which I have brought before you, I can scarcely hope to have

succeeded in adequately explaining the admirable services which he has rendered to Astronomy. I have dwelt upon the refined character of his observations, and the extreme care with which all his researches have been conducted. It is a record of unwearying perseverance to accomplish great work; moreover, it is the chronicle of a masterly attainment of success.

Such achievements as those gained by the spectroscope at Potsdam, reveal to us what Lubbock happily terms "the exquisite possibilities of science." Not only is Astronomy enriched by a series of investigations of the greatest value, but a distinct, and, indeed, marvellous advance is made in our knowledge and conception of the stellar universe.

Notwithstanding many deficiencies, I trust I have been able to justify the action of the Council to you, in their desire to honour, in the highest degree, one who has laboured so earnestly, so devotedly, and with such distinguished success for our science.

*The President then, delivering the Medal to the Foreign Secretary, addressed him in the following terms:—*

Dr. Huggins, It is with peculiar interest I place in your hands this medal, and request you to transmit it to our distinguished Associate Dr. Vogel, who, we much regret, is unable to be present to-day; for I can well understand the satisfaction it must be to you, who occupy so classic a position in Spectroscopic Astronomy, to be the medium of conveying this mark of our highest appreciation to one who has developed with such signal success the branch of Observational Astronomy which you originated in 1868. In congratulating him upon the splendid results he has obtained, we would, at the same time, express the full satisfaction with which we have watched the progress of the important institution he directs, and our obligations for its great services to Astrophysics. Assure him of our continued interest in his valuable researches, and that we trust the knowledge of the high estimation in which they are held, may stimulate him to even greater and more noble achievements, which, with the blessing of health and strength, we confidently expect from him.

The meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected :—

*President.*

Captain W. de W. Abney, C.B., R.E., D.C.L , F.R.S.

*Vice-Presidents.*

W. H. M. Christie, Esq., M.A., F.R.S., Astronomer Royal.
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E. B. Knobel, Esq
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Rev. Walter Sidgreaves, S.J.
E. J. Spitta, Esq.
E. J. Stone, Esq., M.A., F.R.S., Radcliffe Observer.

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